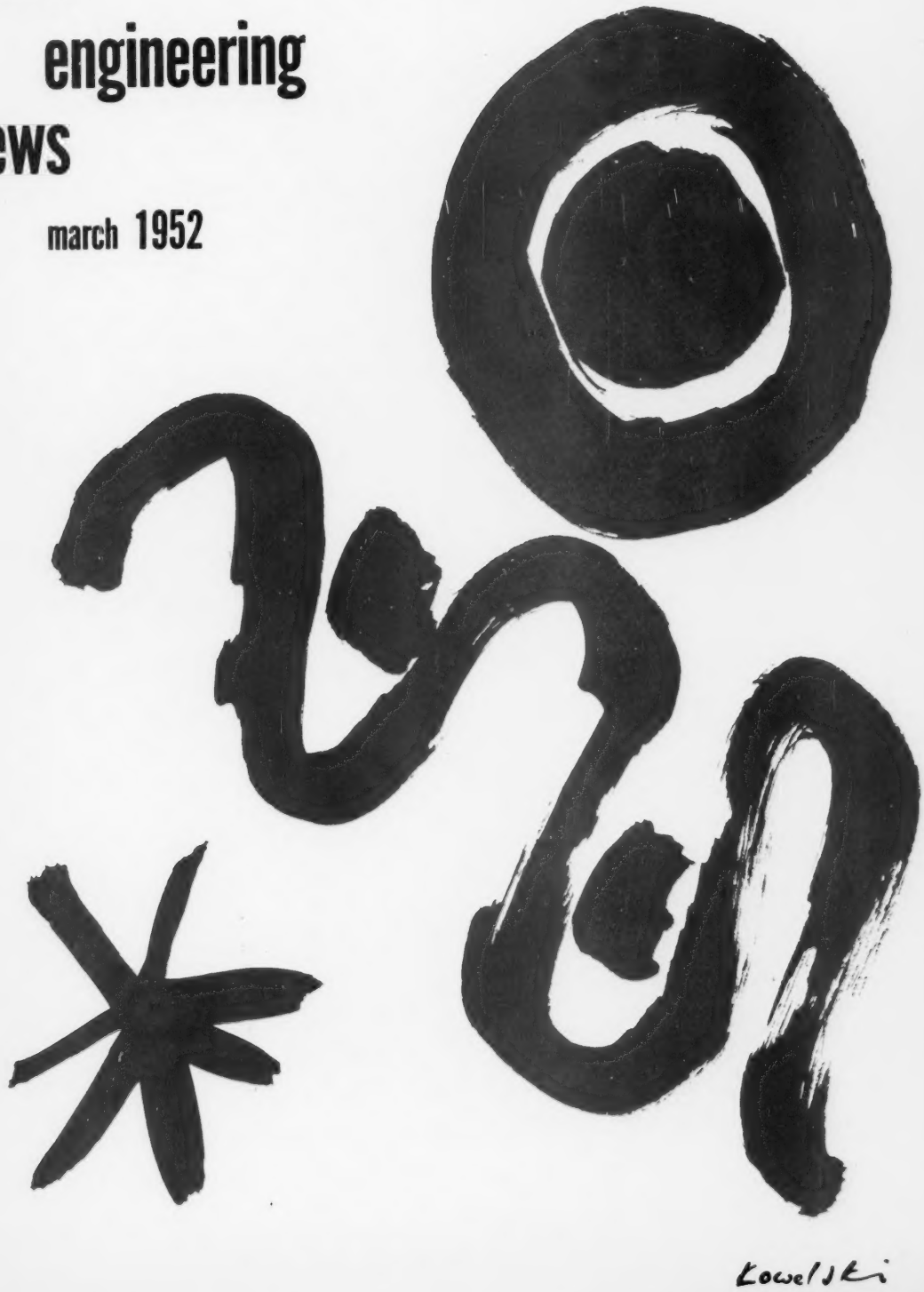
tech engineering news

march 1952



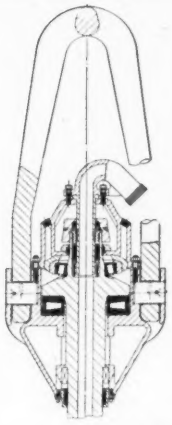
Another page for **YOUR BEARING NOTEBOOK**

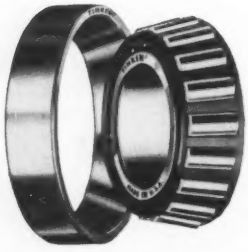
How to keep a drill team from marking time

The swivel on a drilling rig has to carry the tremendous weight of drill pipe that's often three miles long. To carry this load while permitting the pipe to rotate as fast as 250 R. P. M., oil equipment design engineers use Timken® flat thrust bearings in the swivels. Due to line contact between rollers and races, Timken bearings have extra load-carrying capacity. True rolling motion and incredibly smooth surface finish of Timken bearings practically eliminate friction and wear. Costly breakdowns are prevented.

How swivels are mounted on TIMKEN® bearings

The Timken bearing used to carry the thrust load in this typical swivel is an on-apex thrust (type TT) bearing. A single-row (type TS) Timken bearing is used at the top position. Bearing adjustment is made with thin metal shims between the cup carrier and the swivel housing.



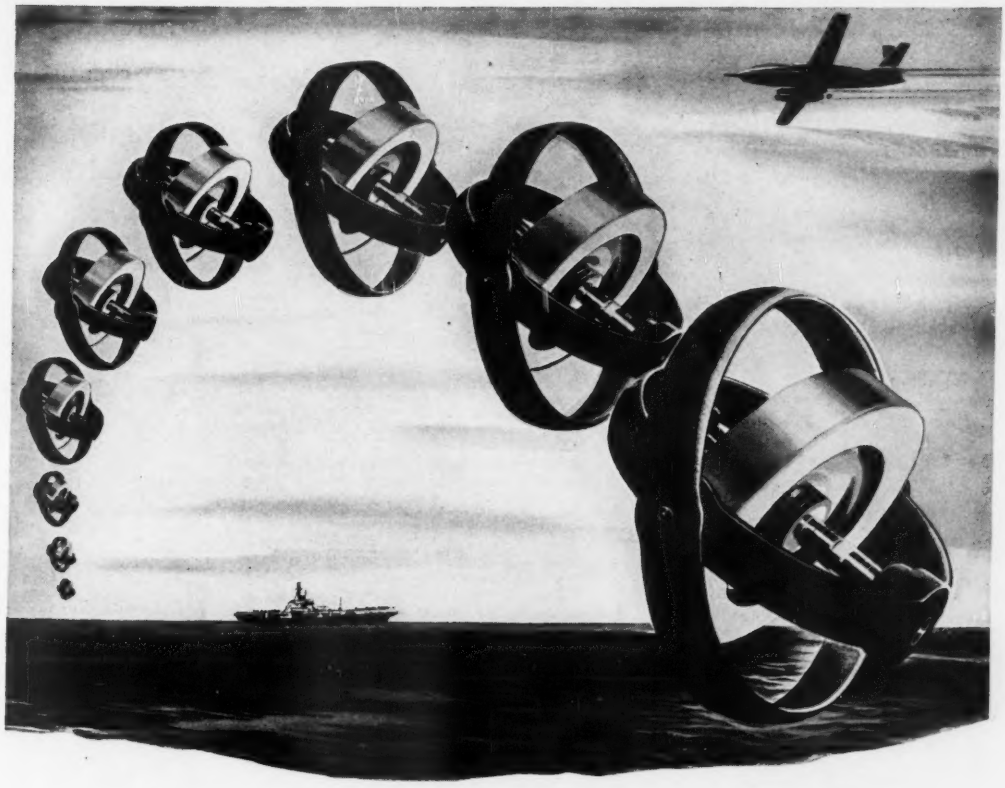


TIMKEN
TRADE-MARK REG. U. S. PAT. OFF.
TAPERED ROLLER BEARINGS

Want to learn more about bearings?

Some of the engineering problems you'll face after graduation will involve bearing applications. If you'd like to learn more about this phase of engineering, we'll be glad to help. For a copy of the 270-page General Information Manual on Timken Bearings, write today to The Timken Roller Bearing Company, Canton 6, Ohio. And don't forget to clip this page for future reference.

NOT JUST A BALL ○ NOT JUST A ROLLER ⬭ THE TIMKEN TAPERED ROLLER BEARING TAKES RADIAL ⬮ AND THRUST —⬮— LOADS OR ANY COMBINATION ✳



Keep Learning...but start earning at SPERRY

GRADUATE ENGINEERS – Join Sperry's engineering team. In one of the research, product development or field jobs now open, you can apply your knowledge immediately and keep on learning with pay.

Good starting pay. Salary increases as you progress. You'll enjoy the advantage of working with acknowledged leaders in their fields. And there are no routine jobs at Sperry. Every job is a challenge to originality, the fresh approach. We offer many incentives for advanced study and the advanced thinking so helpful in getting ahead.

Immediate Openings

. . . for Aeronautical, Electrical, Electronic, Mechanical Engineers – Physicists – Technical Writers – Field Engineers for applied engineering both in this country and abroad.

You'll Work in Long Island

- Attractive location–comfortably outside of but convenient to New York. Good housing and living conditions.
- Modern plant. Well-equipped laboratories. Excellent working facilities.
- Or in the field, there are excellent applied engineering opportunities in other parts of the U. S. and overseas.
- Opportunities for rapid advancement. Encouragement to continue your education, while you earn.
- Liberal employee benefits.

You'll Work Under a Great Leadership Tradition

The Sperry Gyroscope Company–with its 40-year tradition of tackling and solving difficult problems–is the recognized leader in developing automatic controls for navigation. From Sperry's work in gyroscopics and electronics have come the Gyropilot* flight controller, Zero Reader* flight director, radar, servo-mechanisms, computing mechanisms, communications equipment and many other products used in the air, on land and at sea.

Sperry sponsored the development of the klystron tube – the first practical source of microwave energy. From Sperry pioneering have come a complete line of Microline* instruments for precision measurement in the entire microwave field.

We want more men like those who have built up this fine record for Sperry – men who can think and work creatively, and get a thrill out of tackling and solving tough problems. It will pay men with such qualifications to write . . .

Employment Section 1 A 5

*T. M. REG. U. S. PAT. OFF

SPERRY GYROSCOPE COMPANY
DIVISION OF THE SPERRY CORPORATION

GREAT NECK, NEW YORK · CLEVELAND · NEW ORLEANS · BROOKLYN · LOS ANGELES · SAN FRANCISCO · SEATTLE
IN CANADA–SPERRY GYROSCOPE COMPANY OF CANADA, LIMITED, MONTREAL, QUEBEC

Here we go again!

"March 15th, Tax Day, is around the corner . . . and here I am, wrestling with Form 1040 again! You, too, I'll bet.

"Sure, I gripe about it *every* year. Who doesn't? It's like yelling at the umpire. Or beefing about the weather. That's our privilege!

"*But this year's taxes really hurt.* Now don't get me wrong . . . I *believe* in taxes. Can't run a government without taxes. And when it comes to our government spending money *honestly and efficiently* for Defense, Freedom or Good Government . . . it can have the shirt off my back.

"But down at the Republic plant I work hard for my dough. And, naturally, I get burned up when I read about a lot of money being spent *foolishly* by our government. That, of course, goes for all levels of government . . . federal, state, county and local. They're *all* run on our tax money . . . yours and mine.

"And when I say 'our' tax money, it reminds me that *companies* groan about taxes, too. *They've* got 'living expenses' same as we do, and taxes take an even bigger bite out of their income than they do out of ours.

"What's left of *our* pay, we call savings. What's left of a *company's* 'pay', is called profits. It is profits that create new jobs by improving and expanding industry. Without company profits, a lot of us citizens would *lose* our jobs.

"To get back to this business of *spending* . . . my wife runs our home with simple, sensible day-by-day economy. And so do my neighbors' wives. So does any well-managed business. So why shouldn't our government . . . national, state, county and local . . . practice that same common-sense economy, too? With, I repeat, *our* hard-earned dough!"

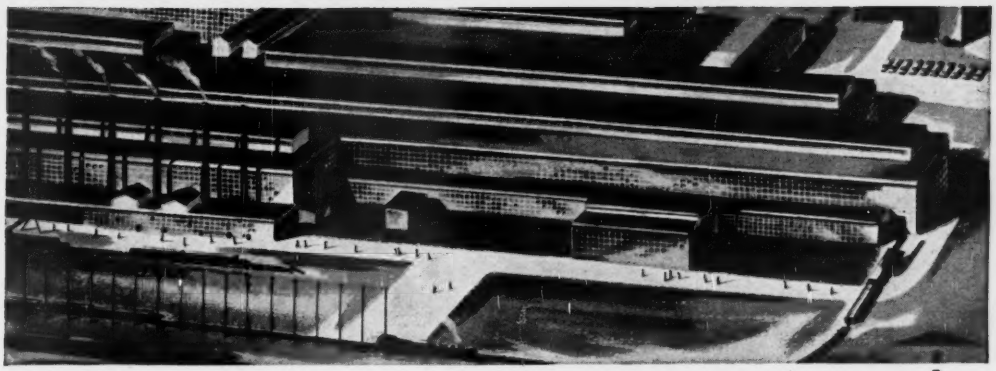
REPUBLIC STEEL

Republic Building • Cleveland 1, Ohio

Republic BECAME strong in a strong and free America. Republic can REMAIN strong only in an America that remains strong and free . . . an America whose vast Railroad Industry is unsurpassed. *And through railroading, Republic serves America.* Republic steel goes into track bolts and spikes . . . and into powerful locomotives that thunder over the tracks. Republic's famed Enduro Stainless Steel is found, inside and out, on gleaming streamliners that crisscross the nation. And in roundhouses and repair shops, tools and machines made of Republic steel help keep America's rolling stock rolling, come peace *or* war.

* * *

For a full color reprint of this advertisement, write Dept. H, Republic Steel, Cleveland 1, Ohio.



MAGNESIUM MILESTONE

at Dow's new Madison Plant

A significant development in magnesium is taking place at Dow's newly acquired magnesium plant at Madison, Illinois. Dow, long a pioneer in the production and fabrication of magnesium, is installing the *first and only continuous magnesium rolling mill in existence today.*

Other mills for magnesium are hand operations in which 140 lb. slabs are broken down and magnesium rolled a sheet at a time, a maximum of 48 inches wide. Dow's new mill will process 2,000 lb. slabs on 84 inch coils, marking a tremendous advancement in production methods and resulting production capacity.

The Madison plant, which has 1,400,000 feet of floor space and 110 acres of land within its boundaries, will house not only this magnesium mill but also facilities for extrusion and alloy operations. It is but one of the many new developments that indicate the continual growth and expansion taking place at The Dow Chemical Company.

Dow's Booklet, "Opportunities with The Dow Chemical Company," especially written for those about to enter the chemical profession, is available free, upon request. Write to The Dow Chemical Company, Technical Employment, Midland, Michigan.

THE DOW CHEMICAL COMPANY
Midland, Michigan

tech engineering news

March 1952

Vol. XXXIII No. 6

Aspirations of M. I. T. Undergraduates 6
By Raymond Blair, '50

Million Dollar Gambles 8
By D. F. Shrader

Fluorine 12
By Knute J. Nomland, '55

The Solid State 14
By Dr. J. C. Slater

Investment and the Engineer 15
By D. F. Shrader

Waves at Work! 16
By Howard F. Davis, '53

Cover Design by Jan Kowalski, '52

FRONTISPIECE

Drilling for Oil

Published monthly during the school year at Walker Memorial, Cambridge 39, Massachusetts, by the undergraduates of the Massachusetts Institute of Technology. Entered as second class matter, at the Post Office, June 1, 1920, at Boston, Massachusetts under the Act of March 3, 1879. Copyright 1952 by The Tech Engineering News. Subscription per year $1.75. Foreign $2.50. One copy 25 cents.

aspirations of m. i. t. undergraduates

By Raymond Blair, '50

(Edited by Norman R. Gardner, '53)

This article is essentially a thesis written as a partial requirement for a Bachelor of Science Degree in Economics and Engineering. It is intended, at this time, to jointly enlighten and relate the reader's own feelings as regards his aspirations to the statistical facts derived from a school-wide survey taken two years ago.

The statistical data can be considered reliable and representative to a very high degree. In general, it has been observed that M. I. T. students have a vivid picture of what the future seems to hold for them and what their goals are. This is to be expected. The very nature of an engineering education is, for better or worse, designed to qualify one for a more or less definite type of position. As regards the liberal arts variety of education, the element of uncertainty is great. From the point of view of long range reality, the difference vanishes to a surprising extent. This fluidity will be brought to light in the next issue of *T. E. N.*, at which time the actual status of the alumni will be presented, also from the vantage of statistical survey.

Before investigating the degree of achievement expected to be attained in certain respects, let us first examine the importance attached by M. I. T. students to various goals. The following question was asked:

> What types of satisfactions do you consider to be most important to yourself?

The list of choices was composed of these items: Monetary success; Fame; Political influence; Happiness in family and social relations; Satisfaction with your own work; and Independence. The order of preference was recorded on a one to six basis — one, indicating the greatest importance, and six — the least importance.

This question has obvious limitations, perhaps the most serious being that it does not provide for the possibility that some goal not listed might be more important to certain individuals than some or any of the points mentioned. Nevertheless, this tabulation has much value.

There was a much closer approach to unanimity in the response to this question than one would have expected in a more general population, which is a commentary on the homogeneity of the M. I. T. group. The general order of preference was this:

1. Happiness in family and social relations.
2. Satisfaction with your own work.
3. Independence.
4. Monetary success.
5. Fame.
6. Political influence.

Table I shows the choice-distribution of the Sophomores, which is typical of all, and Figure 1 presents the same information graphically. A striking feature is the extreme indifference to political influence, which seems much more pronounced than one would expect to find in, say, the average university or liberal arts college. A more detailed analysis will be included in the later inter-group comparisons.

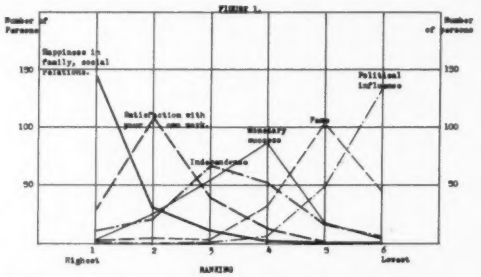
TABLE I

DISTRIBUTION OF RANKINGS BY SOPHS OF TYPES OF SATISFACTIONS

	Ranking	*MS*	*F*	*PI*	*H*	*S*	*I*
Highest	1	3	3	1	145	29	11
	2	25	5	0	30	108	21
	3	54	3	1	11	39	82
	4	86	32	6	2	13	52
	5	18	103	49	1	1	17
Lowest	6	4	44	133	1	0	7

MS Monetary success
F Fame
PI Political influence
H Happiness
S Satisfaction with work
I Independence

Let us now proceed to a consideration of the M. I. T. undergraduate's expectations for the future. The first question is whether studies will continue into the graduate levels. Over one-half of the freshmen entering M. I. T. expect to continue into graduate work, and



nearly one-fifth expect to attain a Ph.D. These percentages steadily fall in the ascending classes, until among the seniors the much more realistic percentages of 32.6 per cent expecting to receive advanced degrees, including 5.8 per cent expecting to reach the Ph.D., are held.

Table III lists the future income expectations of the freshmen, sophomores, juniors, and seniors, as well as the student body as a whole. These estimates are surprisingly uniform as regards the individual classes and fairly realistic. Only when comparisons are made between distinctive groups are any significant variations observed, as will be seen later.

Even more uniform, and perhaps a bit optimistic, is the percentage of Technology students expecting to own their own homes. Ninety-four per cent of the students express this expectation, and this percentage does not vary appreciably even among different courses, both Architects and Electrical Engineers, for example, being 94 per cent expectant home owners. A single exception is the Business and Engineering Administrators, 96.5 per cent of whom expect home ownership.

Thirty per cent of Technology students expect to

own their own businesses. This percentage is quite uniform among freshmen, sophomores, juniors, and seniors (being 30.3, 30.3, 26.9, and 30.6 per cents respectively), but varies widely in different courses, which fact will be discussed later.

TABLE III

FUTURE INCOME EXPECTATIONS

	Starting Salary	*Two Years*	*Five Years*	*Ten Years*	*Twenty-five Years*
Freshmen	$2,770– 4,050	$3,660– 5,230	$5,040 7,850	$7,290– 12,060	$11,870– 28,900
Sophomores	2,990– 4,290	3,700– 5,240	4,870– 6,850	6,670– 10,110	11,000– 19,350
Juniors	2,750– 3,700	3,440– 4,510	4,450– 6,370	6,080– 9,450	9,370– 16,560
Seniors	3,000– 3,670	3,680– 4,600	3,780– 6,630	6,850– 9,750	10,470– 16,850
Total Student Body	2,880– 3,930	3,620– 4,890	4,610– 6,930	6,720– 10,330	10,660– 20,400

Let us now see some of the variations to be noted among different courses. In reference to advanced degrees, Table IV shows that the great variations are related to course, and that the percentage of expected advanced degrees varies roughly with the amount of research which the field of the course involves.

TABLE IV

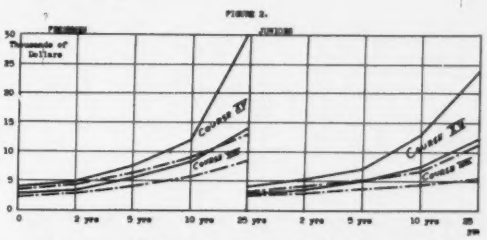
COMPARISON OF ADVANCED DEGREE EXPECTATION AND LATER RESEARCH

Course	*Per Cent of Students in the Course who Intend to Attain Some Advanced Degrees*	*Per Cent of Students who Expect to Do Research after Graduation*
Civil Engineers	17.5	18.35
Chemists	81.3	87.8
Electrical Engineers	58.1	42.4
Physicists	73.5	85.0
Chemical Engineers	53.5	40.3
Bus. and Eng. Administrators	15.1	16.7

With reference to Table IV, it should be noted that the percentages are probably high, but the relative percentages are valid and revealing.

In respect to the nature of beyond-school goals, it will be observed from Table V that the relative order of ranking of "Types of Satisfactions" is the same in every course, with a single exception (to be mentioned); however, there are significant variations in the degree of importance attached to the various goals. For example, the average ranking of the item "Satisfaction with your own work" by the Physicists (Course VIII) is 1.97, while all other courses rank this particular item somewhat lower (e.g., 2.25 by Civil Engineers, Course I). This seems to indicate that Physicists are somewhat more engrossed in their particular work for its own sake than are persons in other Technology fields; at the same time, however, still being in agreement with the others in ranking family and social happiness higher and all other values lower. This appears reasonable.

Similarly, Physicists rate monetary success in a lower position than do any other courses, while still keeping it in the fourth order of the others. This is shown in Figure 2.



Business and Engineering Administration students (Course XV) are just the opposite of the Physicists in these respects (and others also), ranking monetary success higher and work satisfaction lower than do any other courses. In fact, Course XV is the only course which varies from the general ranking order, placing Monetary Success in third place and Independence in fourth. However, this is not so strikingly unique as it may seem since in many courses the relative importance of the third and fourth place is very narrow. But it is significant that Course XV comes out ahead concerning the importance of monetary success. This significance is corroborated in the studies of earning expectations, as will be seen later.

Summarizing the most striking features of the Satisfactions data by courses, we find that Course VIII and Course XV monopolize nearly all the extremes. The Physicists have a lower interest than anyone else not only in Monetary Success but also in Political Influence. They have a higher interest than anyone else not only in Satisfaction with own work but also in Fame. The Business and Engineering Administrators have a higher interest than anyone else not only

TABLE V

AVERAGE RANKING BY COURSE OF TYPES OF SATISFACTIONS

	MS	*F*	*PI*	*H*	*S*	*I*
Course I Civil Engineers	3.50	4.90	5.75	1.29	2.25	3.35
Course II Mechanical Engineers	3.55	5.04	5.47	1.65	2.13	3.22
Course IV Architects	3.94	4.88	5.65	1.64	2.09	2.65
Course VI Electrical Engineers	3.72	5.11	5.68	1.40	2.08	3.00
Course VIII Physicists	4.03	4.64	5.84	1.61	1.97	2.82
Course X Chemical Engineers	3.50	5.14	5.55	1.32	2.16	3.34
Course XV Business and Engineering Administration	3.39	5.05	5.45	1.21	2.39	3.50

(*Continued on page 20*)

million dollar

The Drake well at Titusville, Pa., in 1859 was the nation's first commercial oil well and the real beginning of the petroleum industry.

Surveying crew exploring for oil in Wyoming mountains.

Oil. Black, sticky stuff. Smelly. But necessary to keep all of our complex machinery functioning, and of vital concern to any military power. Our oil reserves are one of the major sources of our strength in the present international struggle. And we are becoming increasingly concerned about the location of new sources of oil.

Men have been trying to find oil ever since the first kerosene lamp was invented. The demand for petroleum has been steadily climbing since, and the invention of the horseless carriage insured that the oil industry was going to keep expanding. Modern mechanization has assured that every nation is crying for more oil, and the United States, the world's greatest producer, is becoming concerned over the rate of consumption of our natural supply. Oil has made the barren, sun-scorched sands of Arabia and Iran the cause of great international friction. The struggle for petroleum could very easily be the spark that touches off another world war.

Vast amounts of research and study have been devoted to methods of finding oil. How successful has this activity been? Considering the amount of work and money that has been put in on the problem, surprisingly little has been accomplished. A good guess is still the driller's best friend. True, major oil companies do not pay geologists very attractive salaries just to wait until an inspiration hits them, at which point they shout "Eureka! Drill three feet west of a crooked tree with a skull and crossbones on it!" A crystal ball is not a recognized piece of equipment for any geologist, and palmistry has not yet made its way into many engineering curricula. But no petroleum expert can be sure that there is oil in any one place until he has drilled there. In fact, if the prospector hits over one producing well in five tries, he is doing better than the national average.

One of the major handicaps of the petroleum geologist is a lack of knowledge of how or why oil was formed in the first place. There are very good indications that oil was formed out of organic matter in a manner similar to coal. The exact details of the process, however, remain a mystery. At any rate, the oil generally collects in a stratum of comparatively loose sand in between the usual layers of rather impervious rock. Lighter than water, the oil percolates upward along the stratum. If there is some sort of trap in the stratum like a "dome" or upward bulge, the oil migrates to the top and collects. Of course the gas which accompanies oil is still lighter and occupies the upper parts of the trap. Below the oil layer there is usually a layer of salt water that has almost the exact composition of sea water, a fact which gives the geologist much room for speculation. If there is no trap at all, the oil, gas, and water are hopelessly diffused. Geologists and their cohorts merely try to find the traps, not the oil directly. Unfortunately, many times oil fails to collect in the most promising of locations, and all of the geologists' hard labors and the company's money have gone for naught.

gambles

By D. F. Shrader

Photos courtesy
AMERICAN PETROLEUM INSTITUTE

The geologist has many methods available for finding the underground reservoir, running from divining rods to thousand-dollar-a-day seismograph crews. One of the cheaper and less unreliable methods in common use is gravity surveying, or using a sensitive balance to determine changes in the earth's gravity from place to place. Its principal virtue is a fairly low cost of survey per unit area.

The use of variations to prospect for oil is based on a simple principle: the presence of any domes or bulges of the dense, lower rocks toward the surface is enough to cause a slight local deviation in the value of "g," and the location of likely drilling spots can be spotted with fair accuracy under favorable conditions, i.e., no mountains or other deflecting bodies nearby. The actual value of gravity is not measured, but only the pattern of deviations in an area. However, the area can be made to include hundreds of square miles. Some of the major oil fields along the Gulf coast of Texas and Louisiana were discovered by gravity methods before seismographs had been used at all.

The principle of most designs of gravity meters lies in having two weak opposing forces, one dependent on gravity, just cancel each other. Then any small changes in gravity will produce large relative changes in the force. Such devices as torsion pendulae or springs provide the gravity-independent forces. These instruments are naturally temperature-dependent, since their metal parts expand slightly, so the temperature is usually carefully regulated for accurate readings. Their size ranges from palm sizes to instruments as large as a keg of Milwaukee's finest.

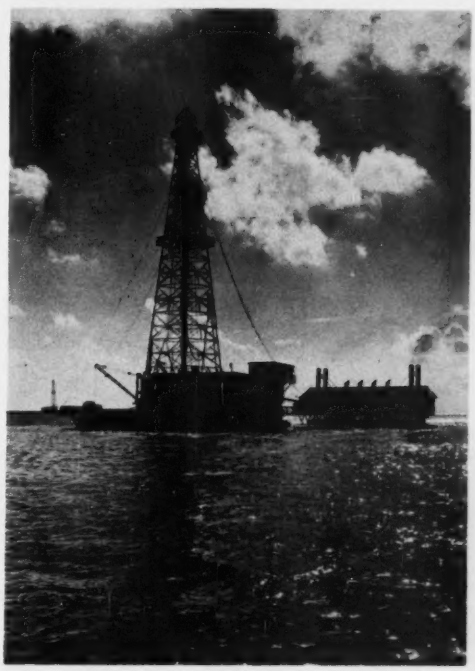
The gravity survey is plagued by a host of corrections which must be applied to the direct readings of the instruments. First of all, there is a correction for the latitude, due to the centrifugal force of the earth's rotation. Then there is an elevation correction involving two terms; the first, the decrease of g with height, second, the increase in g due to the extra layer of rock underneath the higher station. The determination of the elevation relative to the base station naturally involves a surveying crew working within at least accuracies of one foot. How much does the earth's gravity change per inch of elevation? Not very much, but the gravity meters used every day in the field can detect the difference! It is only a change of one part in one hundred million of the total, or 10^{-5} cm per second per second.

After these corrections have been made, the corrected value of each station reading is plotted, and the points of highest gravity indicate upward bulgings of lower strata. These indications are really just qualitative, but they are occasionally sufficient to locate a lot of oil.

The seismograph is still the most reliable, expensive, and widely-used tool in the geophysicist's bag of tricks. The principle involved is quite simple; a small charge of explosive is detonated and a series of shock or sound

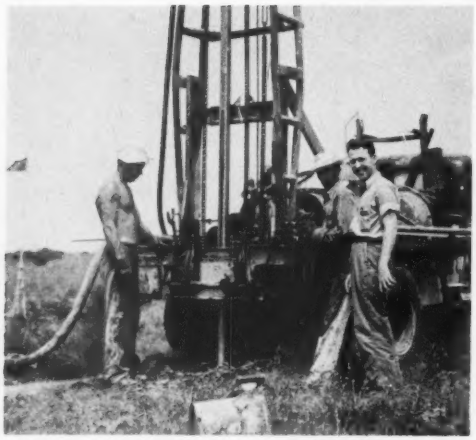
(*Continued on page 10*)

Seismograph crews must go where the oil might be. This one is in a Louisiana swamp.



Oil underneath the ocean is hard to find and drill for.

million dollar gambles



Portable drilling equipment is used to drill the "shot holes" in seismographic surveys for oil.

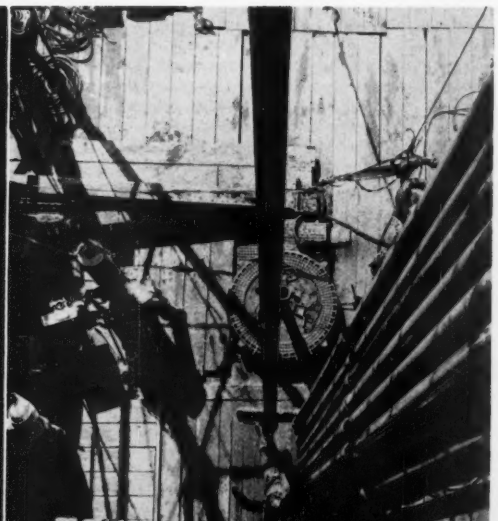
waves is sent through the earth. These waves are reflected from the subsurface rock layers and the echoes are recorded by microphones placed in the vicinity of the explosion. The intensity and time of arrival of these echoes are then interpreted by the geophysicist in an attempt to guess the fault patterns and slopes of the lower strata. The many factors of uncertainty combine to make seismic work far more of an art than a science.

The actual work of obtaining the data is fairly straightforward but expensive. An area which has been selected for investigation (often by a preliminary gravity survey) is surveyed. Then the work of the seismic crew begins. A drill truck, carrying practically a miniature oil well drill, gets to the selected points by some means. If the area is swampy or mountainous, this is one of the major problems of the whole venture. When the site is finally reached, the crew drills a small-diameter hole through the weathered layer of soil and rock extending from twenty to some one hundred and fifty feet below the surface. Then two more trucks arrive on the scene. A shooting truck carries explosives, primers, and detonating equipment. A charge varying from two to one hundred pounds of an explosive similar to dynamite is placed in the hole. The hole is then filled with water to confine the force of the explosion to some extent. Meanwhile, a recording truck crew has unwound some of the large reels of the spaghetti-like wire which the recording truck carries. There are about a dozen very sensitive microphones called geophones, each with separate wires, which have to be placed at intervals of about 250 feet along a line leading away from the shot point. The geophones are simply placed directly on the ground and covered with a shovelful of dirt. When all of the phones have been placed, the recording instruments are checked and the crew stands by for the shot.

The charge is detonated by an electrical pulse from the shooting truck. The entire area trembles, and a dull, muffled roar, deep-throated but not loud, echoes around the countryside. Windows rattle throughout the neighborhood. A geyser of steam and mud is blown fifty feet into the air and spatters down on to the trucks and crew. An acrid stench drifts across the area. The geophones pick up the reflections of the shock waves from the layers of rock from the surface to two miles down.

The signal of the several geophones is recorded on a strip of tape which is marked off in units representing intervals of .01 seconds after the shot. On these tapes, a comparatively huge surface wave hits the phones first and usually runs the delicate recorder off scale. Then there is perhaps a tenth of a second of mild vibrations followed by a period of great disturbance (the reflection from the first rock stratum). Then the echoes from deeper rock layers arrive in jumbled succession. The record is kept for several seconds. The time delay of

Shown below are two views of an oil well and its drilling equipment. On the right workers are getting ready to lower the drill into the well.

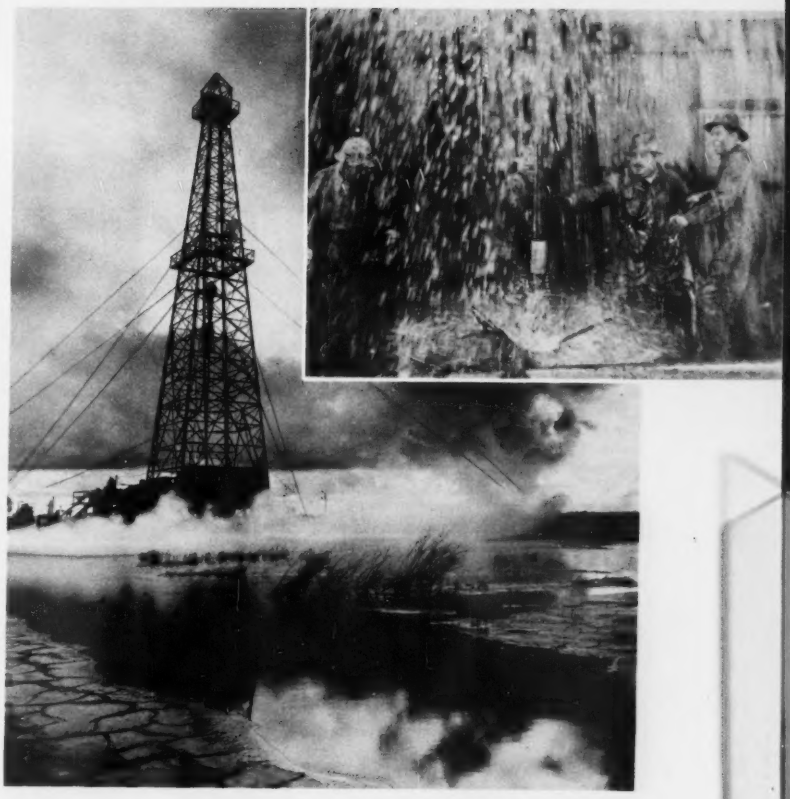


the signal between the stations gives the horizontal velocity of the wave, from which many properties of the vibration can be recognized.

There are three types of waves propagated in all directions from the shot point. First there are ground waves of large amplitude but low frequency (ten to fifteen cycles per second), which are responsible for the rattling of windows in the vicinity of the shot. The recorder is usually made too sensitive to record the large amplitude of this wave, but it tells nothing about the subterranean structure anyway.

The two types of waves which can be recorded are: first, a longitudinal sound wave with a frequency of about fifty cycles per second, moving through the earth at velocities ranging from that of sound in air, or one thousand feet per second, for loose sand or surface soil, to about five miles per second for very solid rocks such as granite or salt beds. The velocity also increases practically linearly with depth, due to the greater pressure on the medium. The variation in the velocity with material and depth gives rise to refraction effects exactly similar to those of familiar optics; so neither the distance the wave has travelled nor the depth from which it has come are proportional to the travelling time.

The third type of shock wave which is propagated through the earth is a transverse wave, resulting from the shearing stress of the explosion. These waves move about half as fast as the longitudinal ones and can be distinguished from them by geophones which are sensitive only to movements in a certain direction, since the directions of movement of longitudinal and transverse waves are perpendicular.



Some of the equipment required to drill a hole three miles deep. (Above) A well drilling for oil in the marshy country of Louisiana.

The geophones themselves are very sensitive but rugged instruments. Most of them work on some principle involving a large mass with an attached coil free to move in one direction within outer coil attached to the light case. These geophones can detect a man's stamping on the ground two hundred feet away, or displacements amounting to only one one-hundred millionth of an inch. They are too sensitive to be used near a city or very close to a busy highway. A person walking across a room will shake the room a detectable amount. Since the mass is free to move in only one direction, the phone of the type described will be sensitive to shocks in only one direction. Sometimes three are used at each station in perpendicular directions, so that the complete motion of the particle can be measured.

Although the interpretation of the irregular lines on the seismograph tape is often open to great debate among competent men, an oil company still considers the seismic evidence the most reliable it has. After considering all the evidence available, such as previous wells which have been drilled in an area, other company's findings (which are closely guarded, of course), or any other information, major companies are usually willing to gamble a cool hundred thousand dollars or so, conveniently tax deductible if they lose, in order to drill a hole straight down for a mile or three below the point their geophysicists indicate. If they are lucky, they will get an oil well. If they fail to get a well in many trials, they find urgent business for their geologists elsewhere.

If anyone could find any method whatsoever to improve the twenty per cent efficiency of present exploration, there would be literally millions of dollars waiting for him. Many have come forth with various schemes, but none have succeeded. It is certainly an interesting challenge.

fluorine

By Knute J. Nomland, '55

Of all the chemical substances known to science, the element fluorine is, without a doubt, the most treacherous and intractable. The strongest oxidizing agent in the electrochemical series ($2F^- \rightarrow F_2 + 2e^-$, $E_0 = -2.85$ V.), this canary yellow gas forms binary compounds with all the metallic elements and most of the non-metallic ones excluding only chlorine, nitrogen, and the inert gases. Some understanding of its extreme reactivity may be gained from a study of its atomic structure. The neutral fluorine atom needs but one additional electron in its outer "valence" electron shell to form a stable ionic grouping of eight electrons. The nearness of this outer shell to the nucleus accounts for the extraordinary tendency of the atom to acquire this extra electron which it holds very securely once in possession of it.

No newcomer to the field of chemistry, fluorine has been known since 1886 when the French chemist Henri Moissan prepared it in a relatively pure form by electrolyzing anhydrous hydrogen fluoride containing some dissolved potassium hydrogen fluoride to render the solution electrically conductive. Moissan's method employed a platinum-iridium alloy U-tube with fluorspar stoppers and electrodes of the same alloy as the tube; the entire apparatus was cooled to a low temperature with liquid methyl chloride. Present day methods of manufacturing the free element use either a process almost identical to Moissan's or one involving the electrolysis of a fused alkali acid fluoride (such as KHF_2 or $NaHF_2$) in a copper or steel vessel with graphite anodes. It is possible to use these metals because they quickly acquire a fluoride coating which protects them from further reaction with the element.

Photo courtesy 3M Chemicals Division of the Minnesota Mining and Manufacturing Co.

Experimental laboratory model of an electrode pack for manufacturing fluorocarbons by electrolysis.

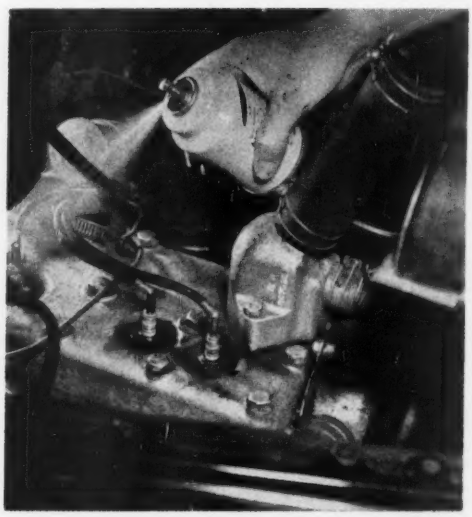


Photo courtesy E. I. duPont de Nemours & Co., Inc.

A "Freon"-propelled aerosol is being used to waterproof the ignition system of this engine. Some day engines like this one will use long-lasting fluorocarbon lubricants and have sealed cooling systems employing fluorocarbon coolants.

Pure fluorine is not found naturally due to its activity. In combination, however, it constitutes roughly 0.1 per cent by weight of the earth's crust; fluorine is about half as abundant as chlorine, which is found in enormous quantities in the salt of sea water. Most widely distributed of the natural fluorine minerals are cryolite, Na_3AlF_6, and fluorspar or fluorite, CaF_2. The latter occurs as beautifully colored cubic crystals which glow when exposed to ultraviolet radiation, hence the term "fluorescence."

Before going into the uses for elemental fluorine and its compounds, it might be wise to look more closely at the element itself. To it is assigned an atomic number of 9 and an atomic weight of 19.00 a.w.u. The fluorine molecule is diatomic (F_2) and has the structure

$$:\ddot{F}:\ddot{F}:$$

Only one fluorine isotope occurs naturally, ${}_9F^{19}$. Several others have been made by nuclear transmutation in

laboratories; these have atomic weights of 17 (half-life 70 sec., e^+), 18 (half-life 112 min., e^+), and 20 (half-life 12 sec., e^-,γ); all are radioactive.

Though a bad actor in anybody's language, fluorine and its various compounds are finding increasingly widespread use throughout the world today.

For many years, hydrofluoric acid has been used in etching glass; the acid reacts with silicon dioxide (the major constituent of most glasses) forming silicon tetrafluoride, a gas. Where a clear etch is desired, the glass is coated with paraffin which is scraped away over the portion to be etched, and then treated with a water solution of the acid. An opaque etch is obtained by using the gaseous hydrogen compound. Glass is frosted by a mixture of ammonium and hydrogen fluorides.

Other uses for hydrofluoric acid are in curing rubber, as a catalyst in the production of high octane aviation gasolines, and for quantitative analytical determination of silica content in the laboratory.

The violent reaction between hydrogen and fluorine (which occurs spontaneously and explosively even at temperatures so low that fluorine is a solid and hydrogen a liquid) is the basis for a recent development made possible only by the increasing commercial availability of elemental fluorine. This development is the hydrogen-fluorine torch, which operates at temperatures in the neighborhood of 6000° F., almost as high as those available through a similar device, the atomic hydrogen torch.

During the war, the atomic energy program nearly suffered a serious setback due to lack of a gaseous uranium compound, urgently needed in a diffusion plant for separating the two naturally occurring uranium isotopes, $_{92}U^{238}$ and $_{92}U^{235}$, only the latter of which is fissionable. The search for such a compound was ended with the discovery that uranium hexafluoride, UF_6, which sublimes above 50° C., filled the bill. Furthermore, pure metallic uranium for the Hanford, Washington, plutonium breeder reactors was made in quantity by the electrolysis of uranium tetrafluoride, UF_4.

Uranium hexafluoride is a highly reactive substance. It was therefore necessary to eliminate from the diffusion system any other substances which would react with it, which meant that substitutes for them had to be found. Here, again, fluorine made a significant contribution to the war effort. The answer to the dilemma was found in the fluorocarbons, a class of compounds having the same carbon skeletons as corresponding organic compounds but with fluorine atoms substituted for the hydrogen atoms. These are made either by conventional catalytic reactions or by electrolyzing a solution of an organic compound in anhydrous hydrogen fluoride. The latter process is much easier to control and makes it possible to retain such functional groups as ether oxygen and amine nitrogen in the fluorocarbon molecule.

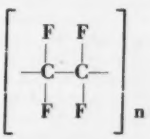
Fluorocarbons are extraordinarily stable (even at temperatures of 500° C.) and absolutely inert. Completely fluorinated hydrocarbons have high densities and the lowest surface tensions of any class of substances. From them can be made highly resistant lubricants and coolants, wetting agents, plastic polymers (which themselves open up broad vistas for accomplishment), and a whole host of other products.

Because of their high electrical breakdown voltages, non-flammability, and good heat absorbing properties, certain liquid fluorocarbons are now used as insulating coolants in a new type of high voltage, liquid-cooled transformer.

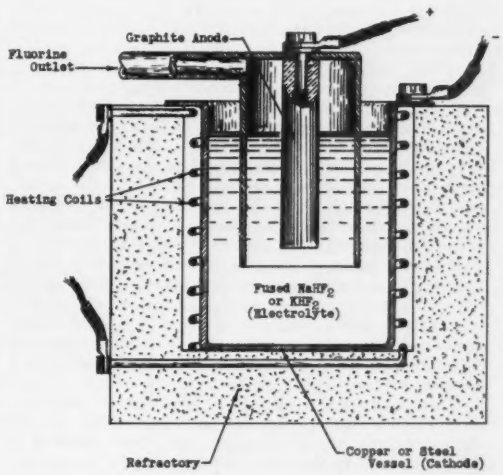
"Freon 13B1" (CF_3Br) is highly efficient as a fire extinguisher and will no doubt come into considerable prominence before long; its vapors are heavy enough to blanket a conflagration and smother it in short order. It is much more suitable for this purpose than the old standby, CCl_4, because it is non-toxic and the products of its decomposition at high temperatures are relatively harmless.

The compound tetrafluoroethylene,

has recently become very important in the industrial world. Under properly controlled conditions, it will polymerize to yield a thermoplastic resin,



"Teflon," which is amazingly resistant to all forms of chemical action, strong, resilient, a good insulator, non-adhesive, and has many other properties which make it unique among plastics. It is currently available as the solid plastic and as a colloidal dispersion used in coating materials and as a base for an enamel.



Electrolytic Cell for Manufacturing Fluorine

Certain halogenated hydrocarbons containing one or more fluorine atoms, marketed as "Freons" ("Freon-12," CCl_2F_2, is typical), have been in use for some time as refrigerants. Their advantage over ammonia, sulfur dioxide, and other such substances lies in that they are non-reactive, odorless, non-poisonous, and therefore harmless in case of a leaky refrigerating unit.

The last few years have seen a phenomenal increase

(*Continued on page 22*)

the solid state

Reprinted from **Physics Today**

By Dr. John C. Slater

The physics of the solid state is nothing new. In 1900 it was as well realized as now that mechanics, heat, electricity, magnetism, optics, all have their solid-state aspects. In mechanics we have elasticity, plasticity, elastic vibrations or sound. In heat we have specific heat, thermal expansion, heat conductivity. In electricity we have conductivity, dielectric constant. In magnetism we have paramagnetism, diamagnetism, ferromagnetism, the Hall effect. Optics involves the refractive index, optical absorption, double refraction, and so on. There are interrelations between different effects: Magnetostriction, the relation between magnetism and elasticity; pyroelectricity, the relation between heat and dielectric behavior; the Faraday effect, the relation between magnetism and optical double refraction; and a host of others. All these were known in 1900, there were tentative theories of many of them, and very elaborate studies of the interrelations of them with crystal symmetry, leading up to the proper mathematical description of many of the properties in terms of tensors, and such mathematical devices.

Why, then, is the physics of solids so much in the forefront just now? Why, in fact, has it had a very much more vigorous development in the present century than it had before? If we analyze the reasons, we see that they are largely two, each of enormous importance in the development of our understanding of the problems. The first is the discovery of x-ray diffraction, more recently supplemented by electron and neutron diffraction, and their application to the study of the properties of solids. The second is the development of the wave mechanics of the solid state, with the understanding it has given us of the motion of the electrons and nuclei which makes up the solid. I shall spend the first part of my talk saying some things about each of these developments, and the sort of results to which it leads; then I shall go over the various classical fields of solid-state physics — mechanics, heat, electricity, magnetism, optics — which still furnish a good classification of the subject, and say a little of the present stage of each, as illuminated by the new knowledge of the present century.

Laue's discovery of x-ray diffraction by crystals, in 1912, and the application of this method by the Braggs to the study of crystal structure, marked a wholly new era in the study of solids. In the meantime, methods have developed until crystals of more and more elaboration can be analyzed. It is worth while realizing that, though diffraction methods are powerful, they still have their limitations; it still takes skill on the part of the analyst to determine a structure. When x-rays fall on a crystal, scattered beams come off in certain definite directions, each beam consisting of a definite wave-length; thus to get all the beams, a continuous spectrum of x-rays must fall on the crystal. There is a very fine piece of mathematics connected with the process, based on the method of Fourier analysis. If we have a crystal with a three-dimensional periodicity, we can expand the charge density in a three-dimensional Fourier series; each of the terms corresponds to a sinusoidal variation of density similar to a plane wave, though standing still in space. Now it turns out that each of these pseudoplane waves is responsible for just one of the scattered beams of x-ray; the scattering is what we should have by ordinary optics from a set of parallel reflecting planes, the spacing being the wave-length of the wave, and the intensity of the scattered beam depends, as we should expect, on the amplitude of the plane wave, or on the magnitude of the Fourier coefficient. Thus from the x-ray pattern we can directly read off these Fourier amplitudes. It would seem, then, that all we should have to do would be to add these Fourier components, or to perform the Fourier synthesis, and we should get the distribution of charge density in the crystal. This could be done, except for one thing: the intensity of an x-ray beam gives us the amplitude of one of the Fourier components, but not its phase. We can see this directly by the analogy of a diffraction grating: if we observe a diffraction spectrum from a grating, we can find the grating

The X-Ray spectrometer which is one of the basic research tools of solid state physics.

space from the positions of the diffraction peaks, we can even determine the details of the rulings by observing the relative intensities in the different orders, but we cannot distinguish between two positions of the grating which would differ only by a motion of a fraction of a wave length in the plane of the grating, perpendicular to the rulings. To supply this missing information, the phases, the x-ray crystallographers have developed a great many devices. Many crystals have enough symmetry so that we can be sure of the phases, except for an ambiguity of sign (which would correspond to a displacement of the wave through a half wave length). Then we can try out many combinations of sign of the most important terms, and see which combinations give sensible answers, which foolish ones, and eliminate the foolish ones. What would be a foolish answer? First, one which gave a density of electrons less than zero. It is the electronic charge density which does the scattering, the x-rays determine this density at all points of space, so that we get peaks of density at the various atoms, with the density going down almost to zero between atoms. Clearly the num-

(*Continued on page 22*)

investment and the engineer

Providing for Your Future

By D. F. Shrader

The engineer prides himself on his logical, pragmatic outlook. He often feels that he knows what he wants and the best ways to obtain these ends. Yet when it comes to the important question of saving for the future, most engineers are no better informed than the majority of the public. This is unfortunate, since the person who is willing to take intelligent risks will almost certainly do better in the long run than one who keeps his money in the bank.

This article is written from the viewpoint of the M. I. T. graduate as he enters industry. He is a young man in his early twenties. His starting salary is about four thousand dollars a year, but he expects to earn substantially more in the future (see page six, "The Aspirations of the M. I. T. Undergraduate"). He is interested in providing for his security and thinks vaguely of retirement, although he finds it difficult to visualize himself in that position. As soon as possible he starts building up a savings account, putting his money in the bank. In this way he provides for the future.

This is the easy way. It involves no imagination, no thought, no risk and little gain. In fact, money kept in the bank in the past ten years has declined appreciably in real value.

What else can be done? Securities, especially common stocks, are an excellent medium for a person just starting his career. I can hear the reply of many of my readers now as they drop the magazine in dismay: "What, speculate in stocks with my savings? Why, I may lose it all!" This belief is founded upon ignorance. If it were true, M. I. T. would certainly be upon shaky foundations, since about forty per cent of its funds are invested in common stocks. The important point to recognize is that an investment in common stocks represents partial ownership of a business, not a worthless piece of paper, and certainly need not be anything like gambling.

What advantages can be obtained from securities investment? People enter the stock market with many different aims. It is possible to obtain a much higher yield than that afforded by banks while still maintaining a substantial degree of safety. An investment in American Telephone and Telegraph common, for example, will yield about six per cent without great risk. This is just one example out of many which can be found.

Other people enter the stock market to achieve very high income (from seven to ten per cent). In this case a comparatively high degree of risk must be taken. There are hundreds of examples of companies whose common stocks afford such high income. Studebaker Corp., yielding nine per cent, is one example chosen purely at random.

There are those people who buy a stock not for income, but in the anticipation that its price will rise in the near future, possibly due to some substantial improvement in earnings, dividends, etc.

An increasing number of people are turning to "growth stocks" for long term investment. In this class we find many young men, looking to the future. The "growth stock" is an investment in a company which appears to be situated in an industry which will experience increasing demand for its products over the coming decades. The investor, in this case, is not interested primarily in present yield. If he has confidence in his judgment, he will not be perturbed by short term fluctuations in the price of the stock. As long as he believes that there is a good chance that in, say, twenty years the company will be handling many times the business it does at present, he will continue to hold the stock in the expectation that the long term price and dividend trend will be upward. In most cases, securities which are considered growth situations are in the scientific and technical specialties. We find large long term investments in chemical companies, in air conditioning, atomic power, and so on. The investment world is putting its faith in the engineer. Investors will profit through the work of the technically trained man. It is unfortunate that more of the engineers themselves do not make use of their knowledge for investment purposes. The technical man who works in a field should be able to make an enlightened prediction as to what methods and products will increase in use. He should, by discussion with friends, be able to determine what companies are efficiently managed. By his close contact with the industry, he will be able to keep a continual check on the welfare of his investments. These advantages, used intelligently, should put the

(*Continued on page 44*)

some companies of interest to specific courses

Course 2

Carrier Corp.
Crane Co.
Joy Manufacturing
U. S. Plywood

Course 3

Cerro de Pasco
Fansteel Metallurgical
Sharon Steel
New Jersey Zinc
Vanadium Corp.

Course 5 and 10

Dow Chemical
Du Pont
Standard Oil (N. J.)
Minnesota Mining and Mfg.
Union Carbide and Carbon
Vitro Chemical

Course 6

Admiral Corp.
International Resistance
Radio Corporation
Dumont Laboratories
Mallory
Zenith Corp.

Course 8

American Research and Development
Consolidated Engineering
Ionics, Inc.
High Voltage Corp.
Tracerlab, Inc.
Vitro Mfg.

Course 12

Ohio Oil
Phillips Petroleum
Texas Co.

Course 16

Bell Aircraft
Solar Aircraft
Garrett Corp.
Eastern Airlines
United Airlines

waves at work

Microwaves Find New Uses Daily

By Howard F. Davis, '53

The history, development of components, and applications for communications with high frequencies started with the detection of reflections of radio waves from metal bodies to the multichannel microwaves systems as we know them today.

Microwaves are those commonly applied to the spectrum of radio waves from 1,000 to 30,000 megacycles per second (wave length from 30 to 1 cm).

The first important observations of microwaves were done by Hertz in 1886 when he demonstrated that radio waves reflected from metal were detectable. In 1925 two Americans, Breit and Tuve, measured the height of the ionosphere with shortwaves, a forerunner of microwave radar. Another step was taken when Marconi set up a shortwave transmitter and receiver between the Palace of the Pope and the Vatican City in 1932. A little later Sir Robert Watson-Watt was the first in England to use a pulse-modulated transmitter and a cathode-ray oscilloscope to form the present type of radar system.

Before England entered the war in 1938, she had a number of such installations, as Watson-Watt had devised, to detect airplanes from the air and land. Some will remember the first N. B. C. television in New York in 1938, and in the World Fair in New York. In 1941 Bell Telephone set up a "single-hop" 12-channel microwave system between Cape Charles and Norfolk. From this time until the end of the war most of the effort was placed on applying microwaves to radar for military uses.

Communications at high-frequencies and microwaves are not the same, but because microwaves have been developed and used so extensively in communications the two terms have become almost synonymous. The possibilities and uses of microwaves for communications were only partially realized and developed prior to the war. As is usually the case, the development during a war is much faster than could have been expected during a similar peace-time period. A great deal of the radar work was done in the Radiation Laboratories here at M. I. T.

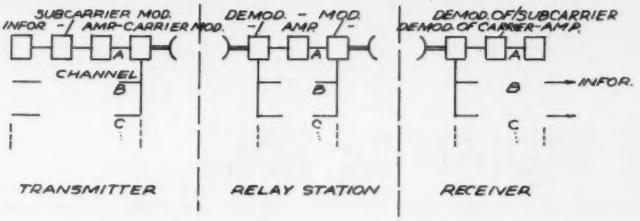
In comparison to broadcast bands (500 kilocycles to 1600 kilocycles), the problems of generation, modulation, amplification, and transmission were in many cases new and more complex for microwaves. For example the transient time for electrons to travel from the cathode to the plate in a conventional triode is a limitation at microwave frequencies. Oscillators which could generate a substantial amount of high-frequency power were not common before the war, and even today they are not as readily constructed as generators of broadcastband frequencies. The early microwave generators were capable of producing only a few watts, but as a result of radar development, peak powers of three and four megawatts have been attained; this is bridging a wide gap in a few years. The magnetron tube is the primary power generator of microwaves at the present; however, research is being done toward using the klystron tube as a main generator.

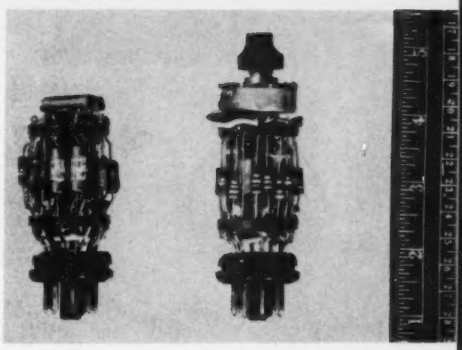
The transmission of microwaves is done by using their optical properties of reflection, diffraction, and refraction. The antennas used in broadcast band transmission are much less directional than those used for microwaves. Microwaves are transported within a station by wave guides (a long rectangular or circular tube) as distinct from the usual parallel wire transmission lines. It is possible to transmit broadcast band waves beyond the line of sight; however, waves of frequencies above 100 megacycles are greatly attenuated along the surface of the earth. This characteristic makes it necessary to have repeater stations along the earth in order to communicate over long distances using microwaves.

At the upper frequency limit, communication on microwaves is adversely affected by absorption and scattering of water vapor and oxygen. The maximum attenuation of oxygen for microwaves is at a wave's length of 1.25 cm (24,000 ϕ megacycles).

But why bother with microwave communication commercially if so many new problems are confronted? There are a number of reasons, but the foremost are:

(Left) One of the relay towers in use along the system. (Below) The coast-to-coast microwave relay network of the American Telephone and Telegraph Co. Relay stations have to be placed every twenty-five to thirty miles along all of the channels.





(Above) A schematic of a microwave sending, relay, and receiving system. (Right) The amplification of microwaves is a difficult problem that confronts the engineer. The left gadget is a square wave generator; the right is a differential d.c. amplifier. They are used for microwave amplification.

(1) The broadcast band waves are crowded. There is a demand for wide band transmission for television (color and black and white). There is a need for multiplying the number of channels for transmission of telephone and telegraph. Bandwidth is easier to achieve at microwaves.
(2) More highly directional antennas of smaller size can be used in microwaves.
(3) Microwave channels are not as susceptible to noises-natural and man-made — as are broadcast band channels. There is, however, an upper limit on the frequency of microwaves.

At the end of the war a number of large manufacturing companies and laboratories were quick to make their bid for a part of the expansive regions of the microwave spectrum opened up by intensive war research and development. Their interests were directed mostly at getting concessions on channels from the Federal Communications Commission, and of getting the most advantageous positions for long-distance relay stations.

Raytheon Manufacturing Corporation indicated a short interest in setting up a nationwide grid system. General Electric and International Business Machine Corporation announced their common interests in commercial applications. Philco started work on microwave relay stations for transmitting television. American Telephone and Telegraph Company commenced work on a system that would greatly supplement their coaxial cable network which was in construction.

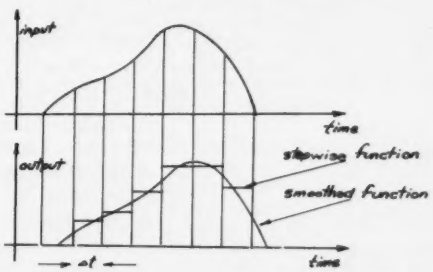
After accepting the task of manufacturing, constructing and maintaining a microwave transmission system, there were numerous problems in adaptation, in a rapidly changing technical field, to make a successful commercial network. Among the problems were:

(1) Channel Divisions.
(2) Propagation of waves.
(3) Generation, modulation, detection and amplification.

It was found that the region from 1,000 megacycles to 10,000 megacycles would be the best for commercial uses. American Telephone and Telegraph's allocation from the F. C. C. was from 3700 megacyles to 4200 megacycles for their TD-2 network. This band width is a terrific expansion of the present radio broadcast bands. An average band width for a broadcast band is 10 kc. A coaxial cable unit is capable of handling transmission frequencies up to a few megacycles. The band width necessary for telegraphy, telephony, and television video are respectively: 0–80 cps, 30–15,000 cps, and 30–4,500,000 cps. Just qualitatively one can see that the expansion from broadcast band to microwave, and from coaxial cable to microwave is exceedingly great.

In transmission there is the question of which is better: lines or relay stations. Relay stations have directional antennas that can confine waves within a cone of two degrees. In building these relay stations, it is necessary to have them in the "line of sight" of each other for reasons mentioned previously. To build and maintain a reliable relay link is an expensive operation.

Assuming that relay stations are in vogue, it is then necessary to design the equipment: tower, protection devices, generators, amplifiers, and modulators. It



The pulse-code method of transmission. The upper graph represents the input into the transmitter. The transmitter sends out pulses of short duration of amplitude proportional to the input. The received signal is smoothed out by the receiver.

may appear out of place to have a modulator in a relay station, but it is at present necessary. Microwaves cannot be readily amplified. It is necessary to amplify sub-harmonic frequencies in intermediate stages between the information (television, telephone, telegraph) and the final carrier of microwaves. By having a subcarrier it is possible to amplify a signal without distorting the information. With this intermediate stage relay stations do not have to be too careful in eliminating non-linearity, and noise introduced in amplification because the information is not directly amplified.

The power generation of microwaves is at the present being done by magnetrons; however, the klystron tube radiation laboratory is being developed to a stage at which it may be utilized as an efficient, high-frequency generator. In the past it has been used as an amplifier

(*Continued on page 48*)

tech engineering news

Professional Journal of the Undergraduates of the
Massachusetts Institute of Technology

Managing Board

CHARLES M. SALTSMAN, '52 . . . . . General Manager
SHERWIN KALT, '53 . . . . . Editor-in-Chief
ANTHONY RANTI, '53 . . . . . Managing Editor
BERNARD GORDON, '52 . . . . . Business Manager

Junior Board

JOHN MATHIS, '53 . . . . . Literary Associate
NORMAN R. GARDNER, '53 . . . . . Literary Associate
HERBERT JACOBSON, '54 . . . . . Make-Up Editor
GEORGE WODOPJANOW, '54 . . . . . Art Editor
WILL THOMPSON II, '53 . . . . . Advertising Manager
HANS AKSELSEN, '54 . . . . . Office Manager
CHARLES HOMSY, '53 . . . . . Sales Manager
JOHN R. SCHRIEFFER, '53 . . . . . Circulation Manager

Staff

DAN BRZEZENSKI, '53
RAY D'ARCY, JR., '54
DONALD ECKHARDT, '55
DAVE KLEPPER, '53
JAN PIOTR KOWALSKI, '52
BERT KRAUSS, '54
KNUTE NOMLAND, '55
VIC SEEGER, '54
D. F. SHRADER, '57
HOWARD SIMMONS, '54

Publisher's Representative

LITTELL MURRAY BARNHILL, INC.
101 Park Avenue, New York
605 North Michigan Avenue, Chicago

from the editor's notebook

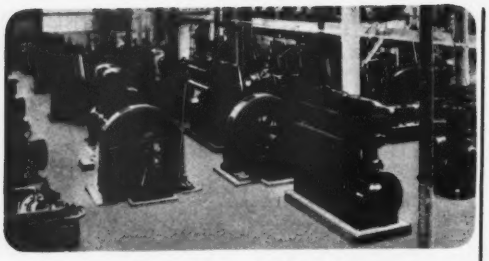
This article was written by ***Eric A. Walker****, Dean of Engineering of Pennsylvania State College, for the* Penn State Engineer. *We think it has a great deal to say to all student engineers.*

Recently, the Department of Defense began to get a little worried about one of its more exotic weapons. This beautiful new tool was not original with our Army, but had been thought up by German scientists during the last war. Fortunately for us, Hitler had no use for scientists except as cannon fodder until he saw he was losing the war. By then it was too late and even German scientific brains could not complete the weapon before Germany fell, and so we fell heir to it. Since the device was so nearly completed, it was thought it would not take long to get it into production. Of course, some small changes had to be made to meet American manufacturing methods and while that was being done some very obvious improvements could be incorporated. However, this still did not make it much of a job and soon our forces should be equipped with a new and wonderful weapon which might stop the enemy cold. At least, that was some one's opinion. The job was given to one of our finest engineering concerns; one with plenty of know-how, plenty of ambition, and a fine reputation. We started to count on having the new weapon in service soon, and indeed, to brag about it. As time went on those who had condoned the bragging as a help to public morale began to ask to see the results, and results, even after six years, weren't forthcoming.

As an answer, the Department of Defense organized a board or committee to investigate the problem. The evidence showed that the whole idea of getting something quickly had been completely lost in multitudinous changes, improvements, and new ideas which had been introduced as essential. Sorrowfully enough, it soon became apparent that even if all the technical problems were solved, it would be three years before the weapon was ready for use. Moreover, it would still take millions of dollars, approximately ten times the original estimate, to complete the job. As the board probed deeper and deeper into what had gone wrong or what hadn't been done right, it became apparent that there had been too little thinking and too much doing. All the effort had been placed on building a machine and trying it, but no one had stopped to question why this particular type of machine was being built and what the tests were supposed to prove. As the unhappy story unrolled, the plant manager became more and more exasperated until he exploded "Dammit, our men have been too busy working to have time to think." To which someone replied "So thinkin' ain't workin'." And this attitude is the key to the whole sorry mess.

Many engineering graduates become administrators. An estimated percentage lies somewhere between ten and fifty per cent. Engineers are proud of this fact; principally, because with administration goes prestige and higher salary. Engineers, in being administrators, are too much concerned with time schedules, personnel, delivery dates, and so on, to do much thinking.

The junior engineer on the test bench or drafting board does a lot of thinking. But he can only think about the details of the job. This leaves no one to do the thinking on the major aspects. For instance, do we design the new automobile engine to run on high octane gasoline or Bunker C oil? Do we power a locomotive with a gas turbine or a Diesel electric plant? Do we build two small dams on a river instead of one big one? Should we build an atom powered electric generating plant or an atom powered merchant ship? These are broad questions of the type that deserves much thought. Usually, the man whose job it is to worry about them is too busy working to have time to think. What we have to do is find some way to honor our thinkers.



Celanese Corp. Uses 6420 Horsepower of Frick Refrigeration

Fourteen Frick refrigerating machines are in operation at the Amcelle plant of Celanese Corporation of America, near Cumberland, Md., makers of chemical yarns. Most of these ammonia compressors have been in use since 1929. The motors driving the new vertical machines, shown in the foreground, are each of 1250 hp.

This is a large-scale example of the dependability and economy of Frick ammonia refrigeration. Power requirements, when operating in summer weather on air conditioning loads, are only 0.70 hp. per ton of refrigeration.

The Frick Graduate Training Course in Refrigeration and Air Conditioning, operated over 30 years, offers a career in a growing industry.

FRICK CO. WAYNESBORO, PENNA. U.S.A.

m. i. t. undergraduates

(*Continued from page 7*)

in Monetary Success but also in Political Influence and Family and Social Happiness. They have a lower interest than anyone else not only in Satisfaction with own work but also in Independence. Mechanical Engineers nearly tie Course XV for highest interest in Political Influence (though still ranking it last), and on the other hand the Mechanical Engineers have the lowest interest compared to anyone else in Happiness in family and social relations (though still ranking it first). Architects nearly tie the Mechanical Engineers in comparatively low rating on Happiness in family and social relations, but the Architects are highest in their rating of Independence. The Chemical Engineers give a lower rating than anyone else to Fame.

The next consideration will be earning expectations as related to courses and other group divisions. A comparison of the earning expectations of the different courses with each other and with those for the undergraduate body as a whole (see Table VI) shows that there is about as much uniformity among the courses as among the various years. Only the Business and Engineering Administrators show an appreciable variation from the average, being noticeably higher. The difference is most extreme in the freshman and junior classes of Course XV. There is a striking comparison between these classes in both Course XV and Course VIII in income expectations. The Course XV men realize a strong drop from optimism to reality, especially in the 25-year bracket. The following is some statistical documentation of the income expectations.

Apart from courses and classes, other group divisions

TABLE VI

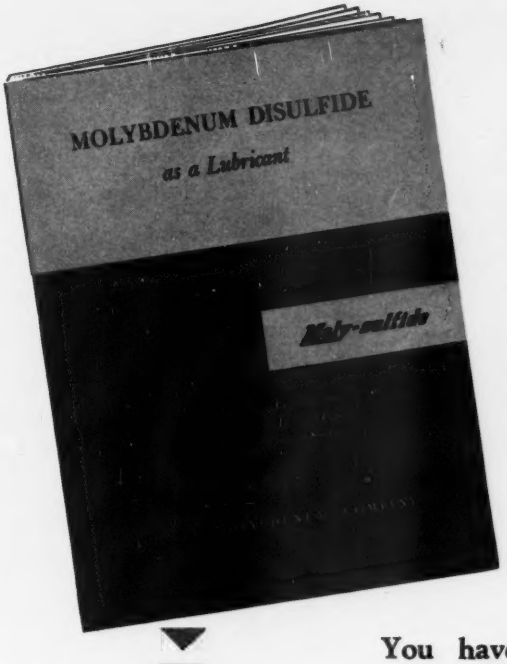
FUTURE INCOME EXPECTATIONS

	Starting Salary	*Two Years*	*Five Years*	*Ten Years*	*Twenty-five Years*
Course II	$2,960– 3,820	$3,670– 4,730	$4,900– 7,220	$6,740– 10,230	$10,830– 18,450
Course VI	2,800– 3,840	3,470– 4,740	4,550– 6,390	6,070– 9,640	9,680– 16,130
Course VIII	2,720– 3,870	3,420– 5,220	4,590– 6,700	6,630– 10,500	9,050– 16,900
Course X	2,990– 3,990	3,620– 4,890	4,610– 6,280	6,620– 9,060	12,830– 19,200
Course XV	2,920– 3,980	3,600– 5,090	5,290– 7,450	7,680– 11,570	13,200– 27,200
Total Student Body	2,880– 3,930	3,620– 4,890	4,610– 6,930	6,720– 10,330	10,660– 20,400

were studied. A large selective sample, drawn from all years and courses, was made of persons from families having an income of $15,000 or more per year. In this group the income expectations proved significantly higher than those of the undergraduate body as a whole. The high-income group reveals several other exceptional characteristics. The percentage of individuals in this group expecting to own their own homes is 97 per cent as compared to the general average of 93 per cent. Business ownership expectation is 63.7 per cent as compared to 29.9 per cent among M. I. T. undergraduates as a whole. The importance-ranking of Types of Satisfactions does not vary significantly from the "normal" except in the feature that this group expresses less interest in Fame than does any other group investigated. Thirty per cent state an intention to participate actively in political life, an intention practically ignored by M. I. T. in general in all courses and years. There is thus an extremely high correlation between the high-income family background and an intention to participate in political life. Yet, paradoxically enough, these persons rank Political influence as of little importance as a type of Satisfaction as do others in general. In reference to future serious employment difficulties, this group rates the probability lower than other groups do. Their average rating is 1.985 (where 1 is very slight, 4 is very high) compared to 2.46 for Economics and Engineering students, 2.28 for Chemical Engineers, 2.27 for Electrical Engineers, 2.18 for Mechanical Engineers, and 2.00 for Business and Engineering Administrators. It is interesting to note that while the curricula for Courses XIV and XV are somewhat similar, Course XIV has a highest concern over future employment difficulties of all courses while Course XIV has the lowest concern of all courses. This fact is probably explained by the newness of Course XIV compared to the well-established and success-traditioned Course XV. The passage of time may have a very changing effect.

Another selective group investigated was those students with a scholastic rating higher than 4.00. No very significant correlations were noted in connection with this group. Table VII, for example, compares average expected income of the High Scholastics with the general expected-income averages, for second-year and fifth-year ranges and twenty-five minimums. The High Scholastics have slightly lower income expectations.

(*Continued on page 36*)



What do you know about MoS_2* as a lubricant?

* Molybdenum disulfide

You have probably heard reports, some enthusiastic, some conservative, of the remarkable properties of Molybdenum Disulfide as a new lubricant.

For those who wish to review published information on this subject, we have compiled a 55 page publication containing excerpts from authoritative technical papers. Copies are free—write now.

Please send your FREE Booklet
"MOLYBDENUM DISULFIDE AS A LUBRICANT"
BLOCK LETTERS PLEASE

Name .....

Position .....

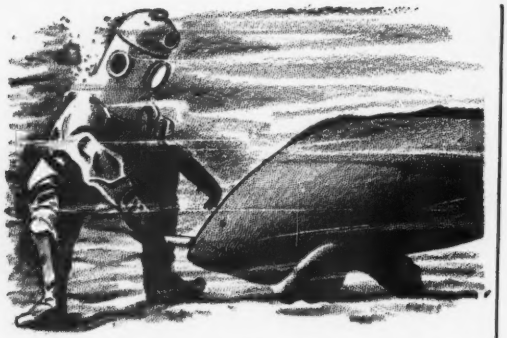
Company .....

Address .....

....

MIT. 3

Climax Molybdenum Company
500 Fifth Avenue · New York City



The wonders of the ocean's floor are duplicated in two giant tanks at Marine Studios, at Marineland, Fla. More than 30,000 live undersea specimens are presented in their natural setting, and into these tanks are pumped more than 7,000,000 gallons of sea water per day.

Okolite-Okoprene cable was selected as the most reliable means of supplying power to the motors which pump this water. Power is taken from a 2300-volt circuit and stepped down to 220-110 volts, for motors ranging from ¼ to 30 h.p.

The corrosive influence of salt water and salt air has virtually no effect on the tough Okoprene sheath which protects Okolite-Okoprene cable.

• • •

Tough jobs are the true test of electrical cable . . . and installations on such jobs usually turn out to be Okonite.

OKONITE insulated wires and cables

8753

fluorine

(*Continued from page 13*)

in the number of commercially available aerosols; one can now buy everything from insecticides and room deodorants to shaving cream, shampoo, furniture wax, and enamels in this convenient form. Aerosols are produced by expelling a mixture of some liquid and a gaseous "Freon" propellant through a small orifice at high (approximately 40 psig.) pressure producing a foam, spray, or invisible mist — one more instance in which fluorochemicals have proven their versatility.

Physiologists believe that fluoride ion is related in some way to the tendency of the blood to clot, and they know that it is an important constituent of bones and teeth.

There are, of course, many other uses to which fluorine is put. Cryolite is important in the production of aluminum from aluminum oxide. Ammonium fluoride is used in disinfecting brewery vats. Sodium fluoride aids in preventing wood rot and is an excellent insecticide. Fluorspar serves as a superb flux and aids in melting substances which are otherwise not easily fused.

Without a doubt technicians and scientists will continue to find more and more applications for this vicious element in the future. The only problem seems to be that of finding fluoride deposits concentrated enough to be profitably worked. This is not an immediate worry, since many adequate deposits are known and others will probably be located easily when the demand for fluorides approaches and threatens to exceed the current supply.

But whatever happens, you may be sure that there's fluorine in your future!

solid state

(*Continued from page 14*)

ber of electrons per unit volume cannot really go negative, and this often eliminates most possible combinations of sign. Then the sign must be such that, if it predicts peaks which must represent atoms, these atoms must lie no closer together than we expect from the known sizes of the atoms. Such a criterion depends on previous experience: if, from the study of crystals starting with simple ones and going to more complicated, we have never seen a case where two particular atoms get closer than a certain value, it is highly unlikely that in a new crystal they would be found much closer. Again, we can more or less identify the peaks, and tell what atoms they represent, by their charge densities (careful work can determine the number of electrons responsible for a peak, to less than a single electron, and hence can determine the atom rather uniquely). We know chemically that some atoms will be found near each other, others will not, and this sort of information can eliminate certain possible arrangements. Finally a structure will be hit upon, by this type of argument; and once it is found, it can be almost uniquely verified, for it can be easily used to predict the missing phases, and then we can do what we could not do directly: synthesize the Fourier series to get the density. When this is done (and the process of synthesizing these three-dimensional Fourier series is a mathematical problem of no mean size, and one which has been mechanized in striking ways in the last years), we have a real picture of the atoms in a crystal. The process of analyzing a crystal is much like that of working a cross-word puzzle. There is no straightforward way to solve it; and yet when it is done, there are so many cross-checks that the probability that the final solution is wrong is vanishingly small.

This gives, then, a little insight into how the x-ray crystallographers work. What do they find? In the first place, of course, they find where the atoms are in crystals. Understandably, this gets increasingly hard as the crystals get more complicated; and while most inorganic crystals have been analyzed, and the simpler organic ones, the more complicated organic crystals are just beginning to be attacked, and very often a very large amount of chemical insight is needed to suggest likely structures, which can then be verified by x-ray methods, as Pauling has recently done in the case of some proteins. The structures which are found obviously fit in with chemistry, and a large part of the recent development in structural chemistry has been closely correlated with x-ray crystallography. Some solids, those held together by covalent bonds, are generally made of molecules, as one can show by finding that the atoms of a single molecule are really clustered together, separated a little more widely from the next molecule. The structure of the resulting molecule is found ordinarily much more easily by x-ray methods than by any other direct process; though the chemists have been so ingenious in the use of indirect evidence that in the vast majority of cases, the chemists had deduced the correct structure on the basis of other evidence before the x-ray method was used. Other kinds of solids show no molecular structure; bonds stretch all through the crystal, as in the familiar ionic crystals like NaCl, made up of ions Na^+ and Cl^-, with no ion being preferentially bound to a single other ion. Ionic crystals are all built this way. So are metals,

(*Continued on page 24*)

In classes like this at the Bell Telephone Laboratories' school for communications development training, college graduates study electronics, oscillations and waves, switching and transmission.

THEY'RE HEADED FOR NEW FRONTIERS

Each year the Bell System selects hundreds of college graduates to learn how to develop, maintain and administer our country's telephone system. Thanks to the competence of our nation's professional educators, these graduates come with an excellent grounding in fundamentals.

Those specially fitted for research, work in the Bell Telephone Laboratories to develop tomorrow's telephone service. In the Western Electric Company, others are planning manufacturing processes or supervising production operations. And in the Bell operating companies, still others are engaged in the engineering and administrative side of telephone service.

More than ever, America's future must depend on men and women who are trained to think far ahead. They are needed both in technology and in administration.

By joining forces with such people, and helping them progress, the Bell System works to keep America's telephones the world's best, and to help the armed forces keep our country safe.

BELL TELEPHONE SYSTEM

(*Continued from page 22*)

the atoms all lying on a simple lattice. So are some crystals, like diamond, graphite, germanium, silicon, carborundum, which are not really either metallic or ionic, being held rather by covalent bonds, but nevertheless without molecular formation. This last group of crystals, some of which are among the hardest materials known, and others among the softest, give some very direct information about the strength of interatomic bonds. Diamond and carborundum are held by covalent bonds, and their hardness shows the great strength of covalent bonds; this is the same sort of strength that holds the atoms together in an ordinary molecule, and which keeps them from breaking up until they reach very high temperatures. Graphite is partly held by Van der Waals forces, the weak type of force holding the molecules together in a liquid or solid, and its softness correlates with the ease of melting a solid or vaporizing a liquid, as compared with the difficulty of dissociating a covalent molecule.

These are just a few examples of the sort of information that we can get about types of solids, and the nature of the binding forces between their atoms. But x-ray methods can go far beyond this. Real crystals are not perfectly regular; and the irregularities are often of very great interest. Three common types of irregularity are those produced by thermal agitation; those produced by damage to the crystal, as cold-work in metals, or by irregularity in growth; and irregularities produced by impurities. X-ray methods are becoming increasingly useful in analyzing all these types of irregularity. We can give an illustration from the case of thermal agitation. The heat motion in a solid can be analyzed into a superposition of plane waves, like waves of sound, having all wave lengths from really long ones (like ordinary sound or ultrasonics) down to wave lengths of atomic dimensions. Each of these plane waves, if it is longitudinal, will produce planes of condensation and rarefaction of density, just like the pseudoplane waves which we mentioned in connection with crystal diffraction, and it can diffract a beam of x-rays in the same sort of way. Of course, to get reasonable angles of diffraction, the wave length of the diffracted wave must be of something like the order of magnitude of the wave length of the sound wave. Thus it comes about that light of ordinary wave length can be diffracted by ultrasonic waves; this is a familiar optical experiment. But x-rays can be diffracted by the shorter waves of sound, and the wave scattered in a given direction gives information about the amplitude of the corresponding sound wave; this is what is called temperature diffuse scattering of x-rays. If we measure the amplitude of a sound wave, and at the same time know that it is produced by thermal agitation, and hence has the energy kT, where k is Boltzmann's constant, T the absolute temperature, then we can find its frequency, for the energy and amplitude are related by a simple equation involving only the frequency. We also know its wave length, from the relation telling the direction in which it is scattered. Then, knowing both wave length and frequency, we can find its velocity. When this is done for waves in real crystals, we find that the velocity extrapolates at low frequency to the observed velocity of sound determined by acoustic experiments, but that at higher frequency, of the order of 10^{13} cycles per second, where the wave length approaches interatomic dimensions, the velocity falls considerably; this is just what theory predicts, and the resulting experimental values, when they are known for more crystals, should be valuable aids in the theory of atomic vibration. This is a striking example of the way in which x-ray methods can supplement other fields, in this case acoustics, and can extend our information to ranges which could never possibly be reached by direct experiment.

Other types of problems where x-ray and other diffraction methods are proving of great value are in studying the electrical and magnetic properties of solids. In the ferroelectric crystals, like barium titanate and potassium dihydrogen phosphate, there is very good reason for thinking that the permanent electric polarization which sets in below a given temperature results largely from the actual displacement of certain ions in the crystal, rather than just the polarization of their electrons. The stable state of the crystal seems to be one in which the ions are displaced to slightly unsymmetrical positions, though raising the temperature makes the ions take up symmetrical positions of slightly higher energy, which do not involve electric moments. Obviously it would be very interesting to check this hypothesis. Until very recently, the x-ray methods were not accurate enough to detect such very small displacements of ions, of the order of a few hundredths of an angstrom. Within the last year, however, measurements of a new order of accuracy have been made, and have actually demonstrated ionic displacement of the general sort that had been postulated to explain these permanent polarizations.

For magnetic problems, neutron diffraction is the ideal tool. X-rays are scattered by the charge density of electrons in a crystal; electrons by the electrostatic potential, which is closely related to the charge density. Neutrons, on the other hand, are scattered by two sources: direct interaction with the nucleus, on account of nuclear forces between the neutron and the nucleons; and magnetic fields, on account of the simple fact that the neutron has a magnetic moment. Magnetic fields of many sorts exist in magnetic solids: fields all in the same direction, but localized largely within the inner shells of the magnetic atoms, in a ferromagnetic solid; in alternating directions in an antiferromagnetic solid; in random directions in an unmagnetized paramagnetic solid, with some preference for orientation in the direction of the field when such a substance is magnetized. In the hands of Shull, neutron diffraction has shown itself capable of giving very detailed information about the magnetic interactions in solids. This is of importance not only for magnetic problems themselves, but for wider reasons: the principal magnetic atoms are those of the iron group; these are among the most important of metals from a practical standpoint, and the same electrons which contribute to their magnetism also undoubtedly take part in their mechanical binding, so that there will certainly prove to be important connections between magnetic behavior and mechanical properties.

These are enough examples to give a suggestion of the many ways in which x-ray methods are giving vital information, beyond the straightforward determination of crystal structure; many other examples could be given, such as their use in investigating cold-work and other imperfections in solids. But next let us go on with the other great advance in the present century in our knowledge of solids, the wave mechanical theory of solid-state structure.

We have every reason for believing that the quantum mechanics, in its present form, furnishes the reliable and fundamental basis for explaining all the ordinary

(*Continued on page 28*)

Acetylene still shows the way

Your nicest textiles—as well as vitamins, headache remedies, plastic garden hose, or welding on your car—may stem from this versatile gas

FORTY YEARS AGO acetylene gas made from calcium carbide was used for home and street lighting, and was in common use for bicycle and automobile lights. Though these old lights have long since gone out, acetylene has gone on to chemical greatness.

IN CHEMICALS—Today, acetylene is the parent of hundreds of chemicals and chemical products used to make plastics, insect sprays, vitamins, aspirin, sulfa drugs and many other things.

Acetylene is the source of some of the basic chemicals in *dynel*, the new wonder textile fiber. It also goes into the Vinylite plastics used in beautiful home furnishing materials, protective coatings, and a host of other products.

IN METAL FORMING—In the production and use of metals, acetylene teamed up with oxygen has revolutionized many industries. From mines-to-mills-to-manufacturer, you will find oxy-acetylene cutting, welding and metal conditioning.

50 YEARS OF PROGRESS—The people of Union Carbide have produced acetylene for over half a century. Through continuous research they have made many remarkable acetylene discoveries important in the lives of all of us.

STUDENTS and STUDENT ADVISERS

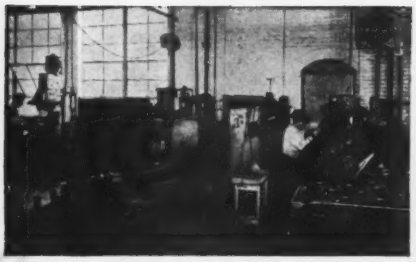
Learn more about the many fields in which Union Carbide offers career opportunities. Write for the free illustrated booklet "Products and Processes" which describes the various activities of UCC in the fields of ALLOYS, CARBONS, CHEMICALS, GASES, and PLASTICS. *Ask for booklet O-2.*

UNION CARBIDE
AND CARBON CORPORATION
30 EAST 42ND STREET UCC NEW YORK 17, N. Y.

UCC's Trade-marked Products of Alloys, Carbons, Chemicals, Gases, and Plastics include

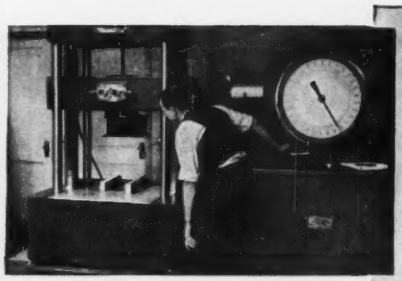
PREST-O-LITE Acetylene • LINDE Oxygen • PRESTONE and TREK Anti-Freezes • BAKELITE, KRENE, and VINYLITE Plastics • SYNTHETIC ORGANIC CHEMICALS
NATIONAL Carbons • ACHESON Electrodes • PYROFAX Gas • HAYNES STELLITE Alloys • ELECTROMET Alloys and Metals • EVEREADY Flashlights and Batteries

Why Grinnell is America's #1 Supplier of PIPE HANGERS *and* SUPPORTS



GRINNELL, ALONE, MANUFACTURES A FULL LINE OF HANGERS AND SUPPORTS

No other company, anywhere, makes a line as complete or varied. Grinnell produces hangers in thousands of combinations to support any piping.



GRINNELL, ALONE, MAINTAINS AN EXPERIENCED LABORATORY STAFF OF TRAINED TECHNICIANS

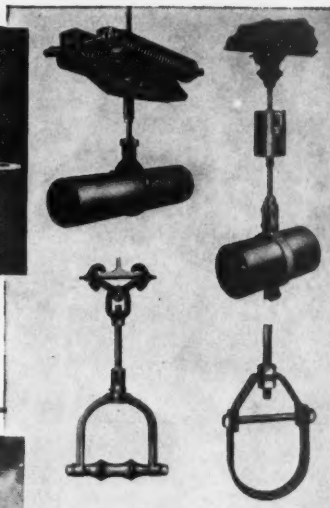
In its modern, well-equipped laboratory, tests are constantly being made to discover better ways of solving old and new pipe suspension problems.

GRINNELL, ALONE, PROVIDES ENGINEERING ASSISTANCE IN DESIGN AND INSTALLATION

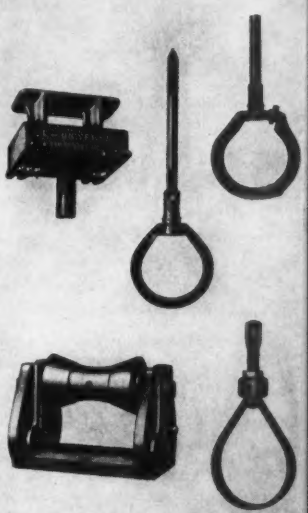
Grinnell makes available specialized knowledge in the computation of hanger loads and the selection of the correct supports. Engineers in the field assist with problems in erection of pipe hangers.

GRINNELL, ALONE, THROUGH ITS CONVENIENT WAREHOUSES CAN SUPPLY YOU "OUT OF STOCK"

No manufacturer of pipe hangers offers a distribution system as thorough or efficient. Grinnell warehouses are located in 30 principal cities . . . with jobbers in practically every city, coast to coast.



Grinnell makes scientifically designed, ruggedly built pipe hangers and supports for every type installation.



Pipe suspension presents an extremely wide range of problems involving weights, stress, thermal movement, materials and specialized engineering. No one "goes into" the pipe hanger business overnight. Large manufacturing facilities, skilled technicians, and a lot of down-to-earth practical experience are needed.

Grinnell has become America's No. 1 supplier of pipe hangers and supports only because Grinnell has specialized in piping for one hundred years. Grinnell has developed a line of pipe hangers and supports for every piping requirement, from the simplest to the most complex.

Grinnell is always ready to co-operate with engineers and architects in the preparation of pipe suspension specifications.

Call Grinnell for any and all types of pipe hangers and supports.

GRINNELL

WHENEVER PIPING IS INVOLVED

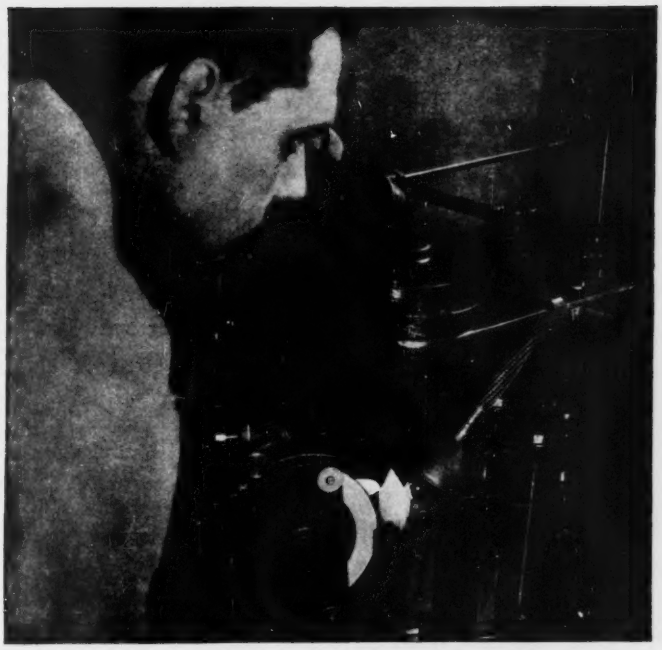
Grinnell Company, Inc., Providence, Rhode Island • Sales Offices and Warehouses in Principal Cities

pipe and tube fittings • welding fittings • engineered pipe hangers and supports
Thermolier unit heaters • valves • Grinnell-Saunders diaphragm valves • pipe • prefabricated piping • plumbing and heating specialties • water works supplies • industrial supplies
Grinnell automatic sprinkler fire protection systems • Amco humidification and cooling systems

ENGINEERING GRADUATES HAVE FOUND ATTRACTIVE OPPORTUNITIES WITH GRINNELL

Who Is He?

- ☐ *a metallurgist*
- ☐ *an expert toolmaker*
- ☐ *a laboratory technician*



If you checked "toolmaker", you know your way around in a machine shop. He's grinding the contour of a carbide-tipped flat form tool on an optical-type precision grinder equipped with a Norton Diamond Wheel.

Facts You Should Know

One of the reasons for the industrial edge the United States has over other countries is its leadership in the use of cemented tungsten carbide tools. With them, American industry has speeded up mass production.

Cemented carbide tools are so hard that they cannot be machined in their ultimate form by any known metal tool. So, they must be shaped by grinding with abrasive wheels.

Diamond wheels have become the accepted type of abrasive wheel for precision grinding operations on cemented carbides. Their exceptionally fast and cool cutting action and extremely low rate of wear result in economically low grinding costs.

Norton Diamond Wheels

Norton Company pioneered in the development of diamond wheels in this country, bringing out the first Resinoid Bonded Diamond Wheel in 1934. This was followed 5 years later by the durable Metal Bonded Diamond Wheel. And in 1945, came the Vitrified Bonded Diamond Wheel, a development of the Norton research laboratories.

Today, the Norton price list for Diamond Wheels and Hones contains about 1000 items, ranging in list price from $17.70 to $2,877.35, depending on the size of the wheel and the diamond content.

Think It Over!

Because Norton Company is dedicated to "making better products to make other products better," Norton Research is always looking ahead. To the young technical man, such a progressive attitude promises an interesting future.

Free Handbook On Grinding Carbide Tools describes in detail how Norton Diamond Wheels are used to recondition and sharpen cemented carbide tools and cutters rapidly and economically. Write for a free copy.

Joseph C. Danec, B. S. Ch.E., Lafayette College '39, examines a diamond wheel section with Bausch & Lomb Research Metallograph in connection with his work on the development of Norton Metal Bonded Diamond Wheels.

NORTON

TRADE MARK REG. U. S. PAT. OFF.

Making better products to make other products better

ABRASIVES · GRINDING WHEELS · OILSTONES · ABRASIVE PAPER & CLOTH

GRINDING & LAPPING MACHINES · LABELING MACHINES · NON-SLIP FLOORING

REFRACTORIES · CERAMIC SURFACE PLATES · BORON CARBIDE PRODUCTS

NORTON COMPANY, WORCESTER 6, MASSACHUSETTS

BEHR-MANNING, TROY, N. Y. IS A DIVISION OF NORTON COMPANY

When the manufacturer wanted to provide this spotlight with a simple, compact means of rotary control combined with push-pull, he used an S.S.White flexible shaft. As you can see, with only a single flexible shaft, the light can be swung 360° or tilted up or down simply by turning the control knob or moving it in or out.

* * * *

Many of the problems you'll face in industry will involve the application of power drives and remote control with the emphasis on low cost. That's why it will pay you to become familiar with S.S.White flexible shafts, because these "Metal Muscles"® represent the low-cost way to transmit power and remote control.

SEND FOR THIS FREE FLEXIBLE SHAFT BOOKLET . . .

Bulletin 5008 contains basic flexible shaft data and facts and shows how to select and apply flexible shafts. Write for a copy.

THE S.S.White INDUSTRIAL DIVISION
DENTAL MFG. CO.
Dept. C, 10 East 40th St. — NEW YORK 16, N. Y.

solid state

(*Continued from page 24*)

phenomena of the structure of solids. From our knowledge of nuclear problems, we are sure that the present form of quantum mechanics is not its ultimate form; there are too many parts of nuclear theory which do not follow satisfactorily from it. But no one questions it in the nonrelativistic range, and the simpler corrections of a relativistic nature are undoubtedly correct; and fortunately this is all that is needed for a quite complete study of the properties of molecules and solids. This then must affect in a rather profound way our whole approach to a theoretical understanding of problems in the structure of solids. We believe that we could derive their whole behavior in a theoretical way from quantum mechanics; hence we are not at liberty to look for alternative hypotheses to explain their properties. Unfortunately, the quantum mechanics of solids is a very difficult mathematical problem; we are dealing with the mechanical problem of the motion of a very large number of particles, all exerting large forces on each other, and whether we are using classical or quantum mechanics this is a problem so difficult that we must make drastic simplifications or approximations if we hope to get anything simple enough to solve. Fortunately there are simplifications available in the problem of the structure of solids, which seem to be adequately accurate and very useful.

These are the approximations leading to the well-known theory of energy bands. They follow the same lines as the Hartree self-consistent theory of atomic structure, and the molecular orbital theory of molecular structure. We know the limitations of the method fairly accurately, and they are serious; nevertheless it is a simple, usable method, it leads qualitatively to a great many results in agreement with experiment, and it seems to be in most respects the best simple approximation we have. In a few simple cases more accurate calculations have been made, by laborious methods which would not be practicable for more complicated problems. Such accurate calculations are of great service in estimating the accuracy of the approximation methods; we can compare the really accurate calculations with the approximate ones, and assume that the comparison is not very different in complicated problems from what it is in simple ones. In such ways we are building up a feeling of confidence in our approximate methods.

These approximations lead to results which by now have become familiar. They lead to an understanding of the difference between electrical conductors and insulators, and predict correctly what substances should be conductors, which ones insulators. They describe correctly the behavior of semiconductors, and this theoretical understanding has led very directly to the great experimental development of the last few years in the use of semiconductors. The theories lead to predictions about magnetic and dielectric behavior in agreement with experiment, and to an understanding of optical properties of solids. On the other side they lead to calculation of the elastic properties of solids, of their mechanical behavior, specific heat, thermal expansion, and so on. In other words, theory has been applied to a great many of the properties of solids, and in general it works out properly. We should give a word of caution here. While a lot has been done by the theory there are many more things that have not yet been carried through. There is by no means complete agreement by all workers as to what methods of approxi-

(*Continued on page 30*)

ME...
an AIRCRAFT engineer?

But I haven't majored in aeronautical engineering

That doesn't matter. Lockheed can train you... at full pay!

It's your aptitude, your knowledge of engineering principles, your degree in engineering that count.

Those—plus the opportunity Lockheed is offering you—are all you need for a career as an aircraft engineer. In Lockheed's special program for engineering graduates, you may go back to school, or you may convert to aircraft work by doing—on-the-job training. But whichever it is, you receive full pay while learning.

But Lockheed offers you more than a career. It offers you a new life, in an area where living conditions are beyond compare. Outdoor living prevails the year-'round. Mountains, beaches are an hour from Lockheed.

See your Placement Officer today for the details on Lockheed's Aircraft Training Program for engineers, as well as the better living conditions in Southern California.

If your Placement Officer is out of the illustrated brochures describing living and working conditions at Lockheed, write M. V. Mattson, Employment Manager

Lockheed Aircraft Corporation

Burbank, California

This Plane made History

The P-38 Lightning – first 400 mile per hour fighter-interceptor, the "fork-tailed Devil" that helped win World War II.

This Plane is making History

The Super Constellation – larger, faster, more powerful; the plane that bridges the gap between modern air transport and commercial jet transport.

This Plane will make History

This plane – which exists only in the brain of an engineer like yourself – is one reason there's a better future for you at Lockheed. For Lockheed will always need engineers with ideas, engineers with imagination, engineers who build the planes that make history.

(*Continued from page 28*)

mation are best in each case. The theory is far from finished, and there is a great deal more to be done. Nevertheless I believe that it is correct to say that we have good hope that the theory, developing as it now is, will prove able to describe the behavior of solids with qualitative accuracy, and that as we can make more accurate quantitative calculations of a higher order of approximation, we can assess better the errors inherent in our approximations, and allow for them. It is only in the last few years that we have begun to have this type of confidence in the theory, and it is clear that as a result of it, the whole understanding of the solid state is placed on a very different basis from what it was only a few years ago. For a proper theoretical treatment of a solid-state problem today should proceed without any arbitrary, adjustable parameters in it; only a few years ago that was too much to hope for. The encouraging thing is that an increasing number of calculations on such an absolute basis are being made, and that when they are carried through, they have proved in each case to agree with experiment to within the estimated errors of the approximation and of the experiment.

We have now surveyed the two techniques by which our knowledge of the solid state has been so greatly advanced during the present century. Let us spend the rest of the time in going over some of the properties of solids, to take a very quick look as to the sort of answers which we have got, by x-ray methods of theory or both, to the questions which naturally arise. Let us divide our analysis according to the conventional subdivisions of mechanics, heat, electricity and magnetism, and optics.

When we consider mechanical properties of solids, there are two sorts of behavior that concern us. First there is the elasticity: compressibility, elastic constants, and considered more broadly, all the forces that hold the crystal together, including those forces usually considered to be chemical. Here we know a good deal experimentally, and in principle we know how to get a great deal of information. The x-ray methods tell us how the atoms are arranged in their equilibrium positions; this tells us where the curve of interatomic energy versus atomic separation has its minimum. Measurements of elastic constants, including measurements like Bridgman's at very high pressure, give us the variation of lattice energy with interatomic distance. Heats of vaporization and dissociation tell us how much energy is required to break the bonds apart. Elastic constants are checked by acoustical measurements, and by the type of x-ray measurement I have mentioned earlier. Theory allows us to estimate the interatomic forces in simple cases, and allows us to extrapolate this knowledge to more complicated materials; it tells us that the interatomic forces are of electrical origin. We feel on quite sure ground as far as these ordinary elastic properties are concerned, though we must admit that real calculations have been made in only very few cases, and a great deal more work will be required before we have really mastered these problems.

The other, and more difficult, side of the mechanical properties of solids comes in the study of plasticity, creep, all those irreversible processes that are of so much practical importance. Here we are on ground which from its nature is much more difficult. A generalization has been arrived at, as a result of the interplay of theory and experiment: all these irreversible processes require for their understanding the assumption that we are dealing with imperfect crystals. Only an imperfect crystal would flow; only such a crystal would show a breaking strength of anything like the observed value; and so on. By purely geometrical study of how atoms can be arranged and disarranged, we have learned a good deal of the type of imperfection concerned in these problems, and we can begin to estimate whether such imperfections are in fact able to explain the actual behavior of solids. This type of problem is rapidly progressing toward a solution; it is a striking fact that far more work is being done at present on the study of imperfect crystals than of perfect ones, and as we shall see the nature of crystal imperfections is of profound importance in electrical and other problems, as well as in mechanical ones. But there are so many types of imperfection, and they are so hard to investigate by direct experimental means, that this branch of crystal physics is probably less advanced than the study of perfect crystals.

The thermal properties of solids are very closely tied up with the mechanical and elastic properties. We have already mentioned the heat of dissociation or of evaporation of a solid. The specific heat, the thermal conductivity, and a number of other properties are closely tied up with the elastic spectrum, since the thermal energy of the solid can be considered as a superposition of elastic waves of an acoustic or ultrasonic nature, with wave lengths extending all the way down to interatomic distances. Other properties with a thermal aspect to them, like viscosity, are closely related to the irreversible elastic properties like plasticity. Really the mechanical and thermal properties of solids are so closely related that they should be considered as forming a single category.

In the electrical properties, as in the mechanical, we find two types of problems: those which depend only on the lattice structure of the perfect lattice of the crystal, and those which are almost completely dependent on imperfections, and impurities. And here again, some of the most important problems in a practical way result from imperfections. Thus the general distinction between electrical conductors and insulators is a property of the lattice, and as we have mentioned, theory has advanced far enough to give a good account of the distinction. Impurities are important in determining electrical conductivity, as has been known experimentally for a very long time, and as we can now understand from the theory. But even more than this, the behavior of the semiconductors is determined almost completely by the impurities which they contain. Until this was understood, and until the experimental problem of preparing semiconductors with known amounts of impurity was solved, the semiconductors were considered to be unpredictable and unreliable materials; but now everyone knows that recent semiconductor developments have brought them into the forefront of the electrical industry and have focused attention on solid state physics as perhaps nothing else has done.

Not only electrical conductivity, but magnetic and dielectric properties of solids have attracted great interest in recent years. The magnetic behavior is tied up, through the electron spin and the Pauli exclusion principle, in a very important way with electrostatic energies and interatomic forces. Our knowledge of magnetism has greatly increased in the last few years. From the experimental side, we understand the domain theory of ferromagnetism very clearly, and now see how many of the most striking experimental phenomena of ferromagnetism, like initial permeability, hysteresis, retentivity, and so on, are results of the rather second-

(*Continued on page 34*)

how hot?

Oxygen bubbled through molten stainless steel scrap, removes impurities and reclaims badly needed nickel and chromium.

how cold?

"DRY ICE" (Solid CO_2 gas) refrigerates your blood donation to preserve its life-giving effectiveness during its flight overseas. This same gas also sparkles soft drinks, and helps keep food fresh.

AN AIR REDUCTION PRODUCT

at the frontiers of progress you'll find

It's a long step from reclaiming highly critical nickel and chromium to the refrigeration of whole blood – yet Air Reduction takes it in stride.

Why? Because Airco's business is the business of America – a corporate family that contributes to the basic activities of American life and industry – a corporate family that depends on each individual member for the techniques and knowledge to benefit industries as diverse as aircraft manufacture and food packaging . . . medical therapy and shipbuilding.

In fact, wherever progress is racing ahead, not inching to new frontiers, you'll find an *Air Reduction Product.*

AIRCO **AIR REDUCTION COMPANY, INCORPORATED**

Divisions of Air Reduction Company, Incorporated,

AIR REDUCTION SALES COMPANY, AIR REDUCTION PACIFIC COMPANY, AIR REDUCTION MAGNOLIA COMPANY . . . *Industrial Gases, Welding and Cutting Equipment* • AIRCO EQUIPMENT MANUFACTURING DIVISION • NATIONAL CARBIDE COMPANY . . . *Calcium Carbide* • OHIO CHEMICAL & SURGICAL EQUIPMENT COMPANY, OHIO CHEMICAL PACIFIC COMPANY . . . *Medical Gases – Apparatus – Hospital Equipment* • PURE CARBONIC COMPANY . . . *Carbonic Gas and "Dry-Ice"* • AIRCO COMPANY INTERNATIONAL . . . *Export* • AIR REDUCTION CHEMICAL COMPANY.

Even in Sub-zero Weather...

COLUMBIA-SOUTHERN CAUSTIC CARS HELP INSURE EASY UNLOADING WITHOUT STEAMING!

During the transporation delays of the 1951 winter, a car of liquid caustic soda was shipped January 25 from Columbia-Southern's Natrium, West Virginia, plant . . . arrived Chicago January 30 . . . spotted February 9 . . . unloaded February 12 *without the use of steam, and with a full line within a minute.*

During this nineteen day period the car was in transit, outside temperatures were mostly below freezing, twice reaching as low as 15 degrees below zero! Yet easy unloading was assured by the efficiency of the Columbia-Southern designed car.

The Columbia-Southern caustic tank car is one of the many valuable contributions to industry made by Columbia-Southern, pioneer in better transportation and handling of liquid caustic soda.

Columbia-Southern's policy is not only to make the highest grade caustic soda, but to ship it with caution and care.

Among the tank car features pioneered by Columbia-Southern are:

• the patented tank car lining which permits delivery of liquid caustic soda without metallic pick-up—in any concentration • the fusion welding which eliminates rivets as a possible source of leaks • increased tank car insulation • greatly improved heating equipment • and numerous other unloading and safety improvements.

COLUMBIA-SOUTHERN
CHEMICAL CORPORATION
SUBSIDIARY OF PITTSBURGH PLATE GLASS COMPANY

EXECUTIVE OFFICES:
FIFTH AVENUE AT BELLEFIELD • PITTSBURGH 13, PA.
DISTRICT OFFICES: BOSTON • CHARLOTTE • CHICAGO • CINCINNATI • CLEVELAND • DALLAS • HOUSTON • MINNEAPOLIS • NEW ORLEANS • NEW YORK • PHILADELPHIA • ST. LOUIS

After orientation in the new Westinghouse Educational Center, assignments are made to various plants to familiarize graduate students with manufacturing processes. In this way, a wealth of experience is gained quickly . . . with the help of experienced counselors you can choose your career with more certainty.

The Westinghouse Plan

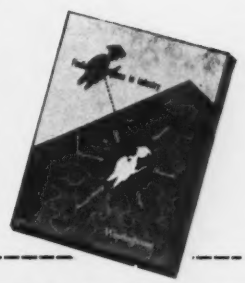
. . . to help you get set quickly

Westinghouse is growing rapidly. Its need for men to maintain this pace is great . . . men who can be developed for responsible jobs—as fast as they can take it.

The Westinghouse Plan is to select top men from top schools; give them a clear, comprehensive understanding of the company and the opportunities it offers in research, engineering, manufacturing and application.

Then, with experienced counselors, you select the type of work in which your education, training and background can be applied most effectively; where you will realize the greatest satisfaction from your work.

With this plan . . . the result of 50 years of operation . . . you can get set quickly . . . for good. It has been proved through the years. For more information about it, send for our 32-page booklet —"Finding Your Place in Industry". G-10172



EDUCATIONAL DEPARTMENT

YOU CAN BE SURE... IF IT'S

Westinghouse

To obtain copy of "Finding Your Place in Industry", consult Placement Officer of your university, or mail this coupon to:

Mr. R. E. Davis
District Educational Co-ordinator
Westinghouse Electric Corporation
10 High Street
Boston 10, Massachusetts

Name_____

School_____ Year_____

Street_____

City_____ Zone_____ State_____

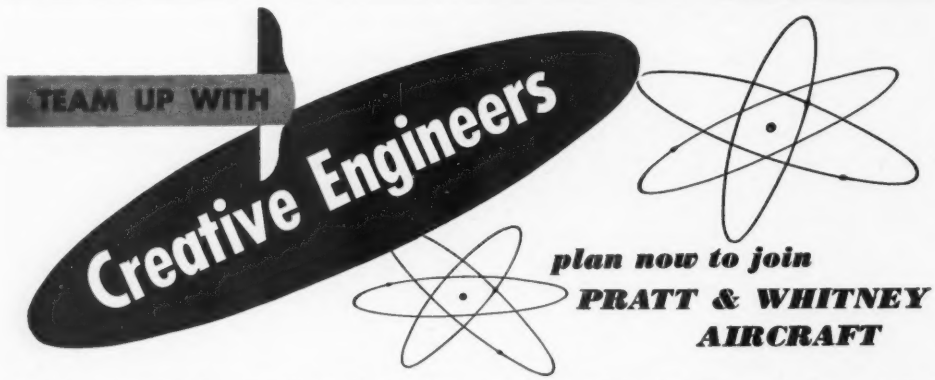
solid state

(*Continued from page 30*)

ary domain behavior, rather than of the ferromagnetic properties of the individual domains and of the perfect crystal. The theory is in moderately good shape; though this is one of the cases where there is by no means full agreement among the theorists as to which approximate form of solution of the quantum-mechanical problem is most appropriate. Antiferromagnetism, the interesting behavior shown by a number of crystals, in which alternate planes of atoms are magnetized in opposite directions, has become of great importance and interest in the last few years. An antiferromagnetic material does not show its behavior by setting up a permanent magnetic moment, as a ferromagnet does, for the obvious reason that some of its elementary magnets point one way, the rest the other way. Its general behavior was worked out from its magnetic permeability, which shows anomalies in the neighborhood of the transition temperature above which it ceases to be antiferromagnetic, and from its thermal behavior in the same neighborhood. And now in the last two or three years neutron diffraction has proved to be an experimental tool uniquely fitted to investigate its problems, for a neutron, being essentially a magnetic probe, sees a great difference between an atom with its magnetic moment pointed one way or the other way, and it is able to give unique answers as to the arrangement of the magnets in antiferromagnetic materials. Here again, as in the ferromagnetic case, the magnetic behavior undoubtedly has a very close relation to the interatomic forces, so that an understanding of these problems is certainly necessary before we can fully understand the behavior of the substances concerned. This is a very important point, for the ferromagnetic and antiferromagnetic materials are among the most important ones from a practical point of view. And here, as with ferromagnetism, there is still far from unanimity among the workers in the field as to the exact nature of the theory to be used.

Finally we come to dielectric behavior, and to the closely related problem of the optical behavior of solids (for we remember that the dielectric constant is but another aspect of the refractive index). Here we find two rather different sources of dielectric effects; we can have induced dipoles on account of the displacement of ions as a whole, or of electrons in the individual atoms or ions of the crystal. The ionic displacement is important only at low frequencies. Ionic vibrations have their resonant or fundamental frequencies, in the infrared, where there is close relation between ionic vibrations and the high-frequency sound waves which we have already mentioned. At frequencies below this, the ionic vibrations are excited with large amplitudes, but they cannot follow frequencies much greater than their resonant frequencies, so that these vibrations are not of importance in the optical properties of solids in the visible and ultraviolet regions. They are essential, however, in a good many important types of behavior: in ordinary low-frequency dielectric constants, in dielectric losses, in the behavior of ferroelectric materials, and in the infrared absorptions of crystals. At higher frequencies, the electronic polarizations are the essential thing (and they cannot be neglected even at lower frequencies, for they have an importance even there which

(*Continued on page 36*)



FOR over a quarter of a century the Pratt & Whitney Aircraft Division of United Aircraft Corporation has depended upon *creative engineering* to bring its products to the forefront.

How well this idea has worked is amply demonstrated by the outstanding leadership record which Pratt & Whitney has established in both piston and turbine aircraft engine types.

And for the future, because of its sound engineering background and research facilities, Pratt & Whitney is one of the few companies in the country to be selected to develop an atomic powered engine for aircraft.

Creative engineering will continue to be given top emphasis at Pratt & Whitney—and it might well be the best answer to *your* future too—if you want a chance to put *your own* ideas to work.

Why not find out where you could fit into this great engineering organization? Consult your Placement Counselor or write to Frank W. Powers, Engineering Department at

PRATT & WHITNEY AIRCRAFT
DIVISION OF UNITED AIRCRAFT CORPORATION
EAST HARTFORD, CONNECTICUT

When You Find the Work You Like

STAY WITH IT!

GORDON W. CLOTHIER

by GORDON W. CLOTHIER, *Manager, Transformer Section, Electrical Department*
ALLIS-CHALMERS MANUFACTURING COMPANY (*Graduate Training Course 1938*)

THAT'S a good plan, but there's just one little catch in it; sometimes it takes a good while to *find* the work that's right for you. If you're worried about that, perhaps my own experience will point out a practical shortcut.

I got my E. E. at the University of Washington in 1935, and went on with graduate work and teaching for another year. Then—into the practical business world. That's when I found the shortcut. I enrolled in the Allis-Chalmers Graduate Training Course in 1936, and very soon I got interested in the big transformers. I've been with them ever since, and they've given me a lot in accomplishment and satisfaction.

Back to Stay

Of course, during two years in the Graduate Training Course I got around a good deal in the big West Allis works. Had some time in the shops, got acquainted with the work of many departments, tried my hand at design, test, sales application work. But I came right back to transformers and have always been a lot more satisfied because I'd seen a broad range of other types of products and work at Allis-Chalmers.

In 1941 I became engineer in charge of transformer sales, and in 1947 was made manager of the transformer section.

This field offers both challenges and rewards. It needs and seeks men of superior intelligence, imagination and creative ability—men who will strike out into new paths of study and development.

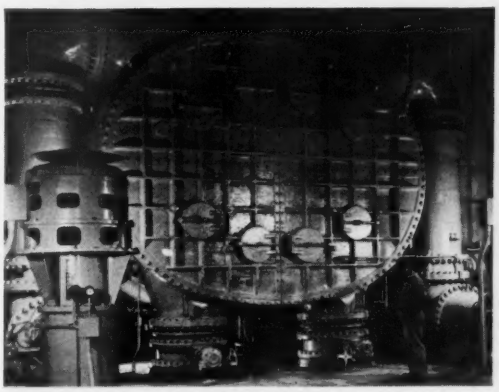
If you think a transformer is an inert mass of iron and copper windings in a tank of oil—look closer. There are advanced problems in magnetostriction that if solved, will eliminate transformer hum and revolutionize the business. It's the same with problems in metallurgy, insulation, measurement and control of electric field shapes and the effects of time on materials. Perhaps some young engineer, even during his Graduate Training Course days here, may make important contributions. The opportunity is waiting.

22-million-volt betatron built by Allis-Chalmers can "look" through 20 inches of steel to detect flaws. Here a technician is setting up motor specimen for radiography.

What Do You Want to Do?

It's the same in other departments at Allis-Chalmers. Ore processing methods and machinery—electronic equipment—public works—steam turbine and generator design—hydraulics—manufacturing—research—sales—they all hold opportunities. Here you'll have a chance, as a Graduate Training Course engineer, to look over the widest range of industrial fields covered by any manufacturing firm in the country. You can help plan your own course, get advanced degrees. It's a shortcut to finding the work of your choice.

Write for information and literature, or call on the Allis-Chalmers district office in your locality.



Two-pass 45,000 sq. ft. surface condenser and two 42" x 30" vertical mixed flow pumps. Allis-Chalmers oval design saved space in this big new power plant.

ALLIS-CHALMERS

Allis-Chalmers Manufacturing Company, Milwaukee 1, Wisconsin

ENGINEERING GRADUATES
CONSIDER YOUR FUTURE IN AIR CONDITIONING
WITH TRANE

Trane, a leading manufacturer of air conditioning, heating, ventilating and heat transfer equipment, is seeking qualified engineering graduates for interesting careers with its sales and home office staff.

Those selected will join the Trane Graduate Training Program at La Crosse for an intensive training course that will prepare them for responsible positions in La Crosse or in one of the company's 80 sales offices. The training period is financed by the company to make the trainee self-supporting.

Men who have completed the Trane Graduate Training Program have established an interesting pattern of success with the company. Included in this number are the president and numerous other company officers, managers of a majority of the sales offices and home office sales divisions.

Trane has continued to grow steadily and at a rate consistent with financial stability. Annual sales have increased fourfold in the last ten years. Yet, the company continues to develop new products for new fields to increase its potential business opportunities.

Based on past record and future possibilities, Trane offers you outstanding opportunities in one of the fastest growing industries. For more information write for the brochure "The Trane Graduate Training Program." It contains full details as well as a complete financial report of the company.

THE TRANE COMPANY
LA CROSSE, WISCONSIN

solid state

(*Continued from page 34*)

is quite comparable with that of ionic displacements). We have a moderately good understanding of the optical properties of solids in the visible and ultraviolet part of the spectrum; though when we come to details, there are very few crystals in which our knowledge is anything like complete, and there is a tremendous amount of work, both experimental and particularly theoretical, which should be done before this problem can really be said to be understood. When we come to the visible and ultraviolet region, however, our attention is not directed so much to the conventional optical problems, the index of refraction and absorption coefficient, but rather to more striking things like fluorescence, phosphorescence, photoconductivity, photovoltaic effect, photoelectric emission, and a variety of other phenomena. Here we are in another of those ranges of effects in which practically the whole thing depends on impurities and imperfections in the crystal. We are beginning to have a general qualitative understanding of how such irregularities of the lattice could allow electronic transitions between excited energy levels of the right sort to explain these phenomena. We begin to see how they correlate with the properties of semiconductors on the one hand, with the mechanical problems of plasticity and such things on the other. But these phenomena are of the greatest complication, and they are exceedingly hard to investigate, on account of the way in which they depend on minute amounts of impurities. The study of such things is a fascinating field, one where much work is being done, but where we cannot be said to have really got to the bottom of the problem in a unique and certain way.

m. i. t. undergraduates

(*Continued from page 20*)

A final consideration is the sorts of occupations anticipated. The specialized nature of M. I. T. training answers that question more specifically in the majority of cases than might be true in universities offering more general education. One statistically measurable point is the percentage who specify in connection with their "ultimate occupation" expectations some major executive capacity. The average is 43.5 per cent overall; 14.9 per cent for Physicists, 29.6 per cent for Electrical Engineers, 46.3 per cent for Chemical Engineers, 51.3 per cent for Mechanical Engineers, 72.7 per cent for Economics and Engineering students, and 77.6 per cent for Business and Engineering Administrators.

TABLE VII

COMPARISON OF HIGH-SCHOLASTICS FUTURE-INCOME EXPECTATIONS WITH THE "NORMAL"

	Two Years	*Five Years*	*Twenty-five Years*
High Scholastics	$2,850–4,140	$4,380–6,320	$10,050–
Total Student Body	$3,620–4,890	$4,610–6,930	$10,660

Do students think that M. I. T. provides them with a satisfactory training for the work they intend to pursue? Students entering M. I. T. have on the average a somewhat higher opinion on this point than they do later on. In fact, this opinion falls steadily from the freshman to the junior years, whereupon it recovers somewhat among the seniors. Ranking a "Very Satisfactory" answer as 1, "Adequate" as 2, and "Not satisfactory" as 3, we may rate the freshmen opinion of satisfactoriness at 1.31, the sophomores at 1.46, the juniors at 1.69, and the seniors at 1.48. Among the major courses, the Chemists (V) are most satisfied with their training (1.28) followed by the Business and Engineering Administrators (1.32), Physicists (1.38), Electrical Engineers (1.46), Chemical Engineers (1.49), Geologists (1.53), Economics and Engineering students (1.63), Mechanical Engineers (1.70), and Architects (1.77). The Civil Engineers (1.85) are the least satisfied of all with M. I. T. as a preparation for their occupation.

The specific expected positions, when specific positions were mentioned, relate closely in general to the course being pursued. But there are some sufficiently startling exceptions to show that within M. I. T.'s uniformity there are sparkles of diversity. One Civil Engineer intends ultimately to be a storekeeper. An Architecture student plans eventually to be a housewife (a fairly uncommon objective at M. I. T.!). A Mechanical Engineer plans to become a night-club operator. Another expects to start out as a "physical laborer." (To ward off any obvious suspicion he emphatically asserts, "Not a joke! I mean it!"). A Metallurgist aims at ranching. And one Electrical Engineer expects, after a post-graduate year at a seminary, to become a radio missionary of the Gospel. Disregarding the Who's Who in America, he asserts (with every evidence corroborating his seriousness and sincerity) that he has 1,000 chances in 1,000 of making Who's Who in Heaven, which is much more important!

THE DU PONT DIGEST

Operator and foreman *check raw material data on a production control board which records every operation in a Du Pont plant.*

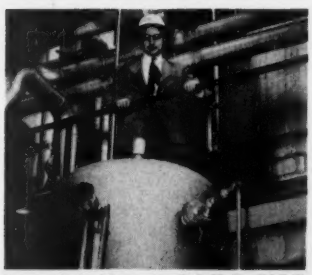
Ch. E's at Du Pont

[THIRD OF A SERIES]

Work as production supervisors prepares chemical engineers for jobs in management

The last issue of the *Digest* described the broad opportunities offered chemical engineers in research and development at Du Pont. Now let's look at the opportunities in production supervision.

In this important phase of plant operation, Ch. E.'s and others are responsible for investment in plant facilities, supply of raw materials, supervision of operation and maintenance, cost and shipment of finished products, as well as personnel relations, training and safety.



George B. Bradshaw, Jr., *B.S.Ch.E., M.I.T. '40, assistant superintendent, inspects a unit used in ammonia synthesis operation.*

Normally, chemical engineers enter production supervision by reason of preference and special abilities. Their first step depends on which of ten operating departments they work in. For example, in one department they follow a training program as student operators. In another, training in a plant laboratory familiarizes the engineers with processes and products.

After the training period, the men are given supervisory responsibilities, usually starting as foreman. At this level they meet problems like these:

1. Occasionally, in a still connected to a sulfonator by a pipe line with a single valve, the product disappeared, and residue increased. The supervisor's study of control data showed that small amounts of gaseous sulfur trioxide were venting into the still causing decomposition of the product. His recommended installation of a positive pressure block in the pipe line eliminated the difficulty.

2. A high temperature batch reaction process was revised to increase production of a critical material. For safety, adjacent reactors had to be shut down as work on each unit proceeded. The supervisor planned maintenance and batch schedules to minimize costly down-time and re-trained personnel for the new process.

In solving such problems, supervisors have an opportunity to use all their knowledge and ingenuity. Equally important, they acquire the background and varied experience that prepare them for advancement to responsible positions in management and administration.

Inspecting nylon *filaments during manufacture. They are made by extruding molten polymer through spinnerets under pressure.*

NEXT MONTH—The fourth article in this series will deal with process development—to many engineers the most interesting part of plant operation.

Conrad R. Graeber, Jr., *B.S.Ch.E., Lehigh '51, control supervisor, examines flow sheets for the manufacture of methacrylates.*

SEND FOR your copy of "The Du Pont Company and the College Graduate," 40-page book describing opportunities for men and women with many types of training. Address: 2521 Nemours Building, Wilmington, Delaware.

DU PONT
REG. U. S. PAT. OFF.

BETTER THINGS FOR BETTER LIVING
. . . THROUGH CHEMISTRY

Entertaining, Informative — Listen to "Cavalcade of America," Tuesday Nights, NBC Coast to Coast

THE HYDROSTATIC TEST

Nobody can buy a length of cast iron pipe unless it has passed the Hydrostatic Test at the foundry. Every full length of cast iron pipe is subjected to this test under water pressures considerably higher than rated working pressures. It must pass the test or go to the scrap pile.

The Hydrostatic Test is the final one of a series of routine tests made by pipe manufacturers to assure that the quality of the pipe meets or exceeds the requirements of standard specifications for cast iron pressure pipe.

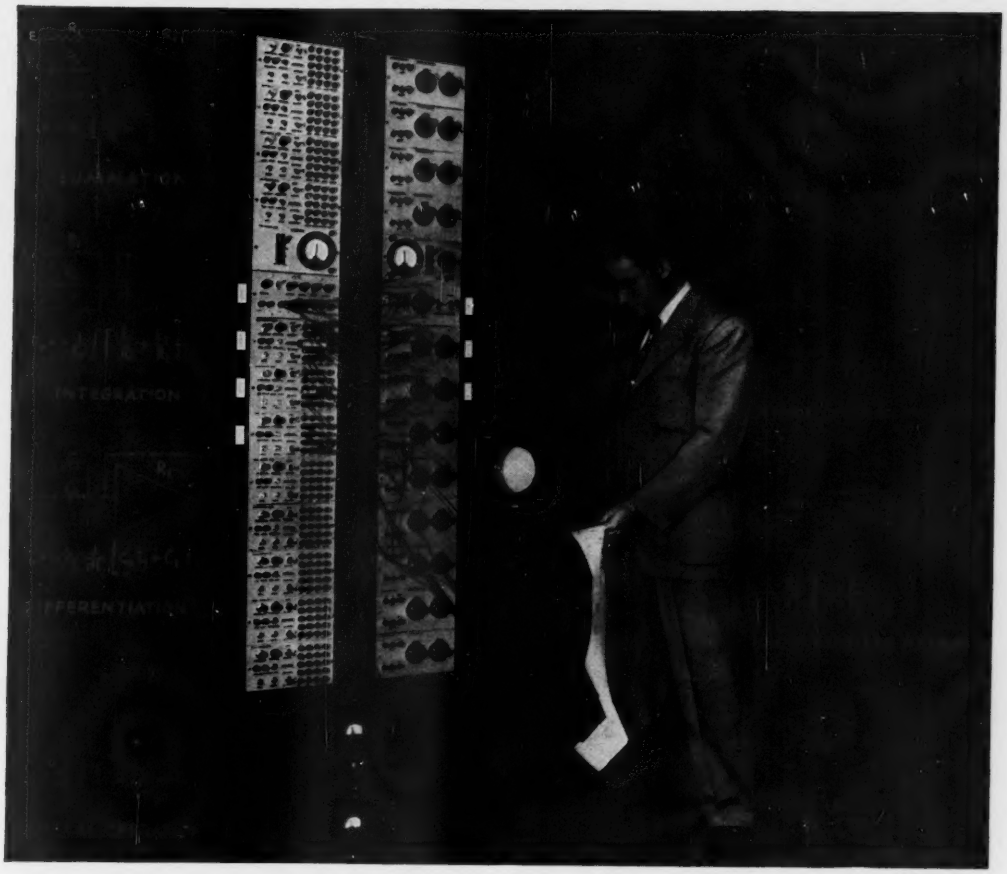
Few engineers realize the extent of the inspections, analyses and tests involved in the quality-control of cast iron pipe. Production controls start almost literally from the ground up with the inspection, analysis and checking of raw materials—continue with constant control of cupola operation and analysis of the melt—and end with inspections and a series of acceptance and routine tests of the finished product.

Members of the Cast Iron Pipe Research Association have established and attained scientific standards resulting in a superior product. These standards, as well as the physical and metallurgical controls by which they are maintained, provide assurance that cast iron pipe installed today will live up to or exceed service records such as that of the 130-year-old pipe shown.

Cast iron pipe is the standard material for water and gas mains and is widely used in sewage works construction. Send for booklet, "Facts About Cast Iron Pipe." Address Dept. C., Cast Iron Pipe Research Association, T. F. Wolfe, Engineer, 122 So. Michigan Ave., Chicago 3, Illinois.

Section of 130-year-old cast iron water main still in service in Philadelphia, Pa.

CAST IRON PIPE SERVES FOR CENTURIES



Solving a dynamics problem with the Boeing Computer; oscilloscope at right shows result.

What's it like to be a Boeing engineer?

Boeing engineers enjoy many advantages – among them the finest research facilities in the industry. These include such advanced aids as the Boeing-designed, Boeing-built Electronic Analog Computer shown in the picture above.

This is part of the stimulating background that helps Boeing men maintain the leadership and prestige of an Engineering Division that's been growing steadily for 35 years.

If you measure up to Boeing standards, you can share that prestige. And you'll work with renowned engineers on such vital projects as guided missiles, the still-classified B-52, the record-shattering six-jet B-47, and other outstanding developments.

You can work in Seattle, in the Pacific Northwest, or in Wichita, Kansas. You will benefit from in-plant training programs, from merit reviews that enhance advancement opportunities. You'll be part of a distinguished, long-range Engineering Division. You'll be proud to say, "I'm a *Boeing* engineer!"

So plan *now* to build your career at Boeing after graduation. Salaries are good, and they grow as you grow. Boeing has present and future openings for experienced and junior engineers for aircraft

- ***Design***
- ***Research***
- ***Development***
- ***Production***

also for servo-mechanism and electronics designers and analysts and for physicists and mathematicians with advanced degrees.

For further information, consult your Placement Office, or write:

JOHN C. SANDERS, Staff Engineer – Personnel
Boeing Airplane Company, Seattle 14, Washington

BOEING

briefing the news

Atomic Power for Industry . . .

Although atomic power for industrial use is still in the long-term future, atomic energy is now being used in such diverse jobs as studying plant growth and measuring wear on automobile piston rings. Atomic energy also is being used to detect impediments in pipelines, to aid in determining how metals corrode, and to help in the search for better metals for aircraft gas turbines.

These and numerous other applications of atomic energy are being accomplished through the use of radioisotopes, materials which have been exposed to radiations of atomic reactors and which emit particles and rays that can be detected by scientific instruments such as a Geiger Counter.

In studying processes of plant growth scientists have mixed radioactive phosphorus with fertilizers. As the phosphorus travels through the roots, stem and leaves, its radiations permit its progress to be closely followed, showing where and how quickly the phosphorus is utilized by the plant.

Wear on piston rings was measured by an oil company, which wanted to test effectiveness of cylinder lubricants. The rings themselves were exposed to atomic rays, and so became radioactive. After they had been used on very short runs, the wear could be determined by measuring the radioactivity that had gotten into the oil.

There is also an application to long-distance pipelines, which are cleaned by forcing through a scraper by the pressure of the fluid being carried. Occasionally a scraper becomes stuck, blocking the line, and it is often difficult to find its position. However, by incorporating some radioactive material in the scraper, it can be located by a man walking along the line with a counter.

Similarly, in working with metals, such methods enable the location of particular atoms to be determined. Thus, one may find just where rust or corrosion forms, or where alloying elements added to a melt are deposited in the solid metal, thus allowing significant study toward better metals.

There are possibilities of using atomic by-products. When plutonium for atomic bombs or other uses is made in the great reactors at the Hanford Works, in Washington, the breaking up, or "fission," of uranium atoms leaves a wide variety of radioactive "fission products" which have thus far found little use. Possible applications for them have recently been explored by the Stanford Research Institute, at the request of the Atomic Energy Commission.

These studies indicate surprisingly large potential markets in various segments of industry. Possibly radiations from these products can be used to sterilize materials without the usual heating. These methods may be especially applicable to pharmaceutical products which are easily destroyed by heat.

While no very tangible results had yet been obtained in generating useful power from atomic energy, some real progress has been made. Some GE engineers do not envision any possible way to produce significant quantities of electrical energy directly from fissioning atoms, but they can get lots of heat.

When an atom fissions the two fragments fly apart at tremendous speeds. Within a submicroscopic distance they are stopped by the surrounding atoms, and thus release their energy as heat. So great is the amount that if we cause complete fission of one pound of atomic fuel, we should get approximately the same amount of heat as from burning 1500 tons of coal, a ratio of three million to one.

The first full-scale application of atomic power will probably be in a submarine power plant. It has the advantage that the initial charge of fuel will be sufficient to run the submarine for many months without refueling. Moreover, since it does not need air in order to "burn," the craft could operate underwater at full power for very long periods of time.

The present world situation may have a bearing on the economic feasibility of atomic central power stations.

At present our country seems to need as many atomic bombs as it can afford. Apparently the use of atomic bombs is considered to be an economical way to wage war, if there is any economical way. Therefore the price which the government can afford to pay for plutonium for bombs is many times more than the plutonium would be worth as a power plant fuel.

"A dual purpose plant, making plutonium and selling it to the government and also generating and selling power to the public, might pay," says H. A. Winne of GE.

"Such a plant might be profitable long before we have developed processes sufficiently economical to permit a plant to recycle its plutonium and produce power only."

Four groups, each including a private power company, are now studying this problem with a view toward active participation by industry in the atomic power field.

Native Intelligence Declines After 35 . . .

Biological or native intelligence, as expressed by the functioning of the human brain and nervous system, begins to decline past the 35th birthday, a University of Chicago psychologist reported to the American Psychological Association.

Ward C. Halstead, professor of experimental psychology, discussed the physical aging of the human brain, based on a group of tests he has developed in 16 years of research.

Though all brains do not age at the same speed, the decline in brain power past the 35th birthday tends to be slow at first, then proceeds more rapidly.

Halstead points out, "A man of 50 may have the brain power of a man 20 years younger, even though his chassis, joints and muscles may have begun to creak under the strain of living."

Unfortunately, the reverse is often true, and especially is notable among professional and executive groups. The current problem of leadership in the United States, Halstead believes, is much less a question of chronological age, than of a man's neuro-psychological age.

Biological intelligence, measured by Halstead, consists of four main factors determined by four main groups of tests. One group of special tests measures the ability to think abstractly according to a definite standard.

One simple example of this factor is the ability to use a telephone book, where names are grouped alphabetically. Halstead has developed an apparatus to measure this factor, which requires an individual to

(*Continued on page 44*)

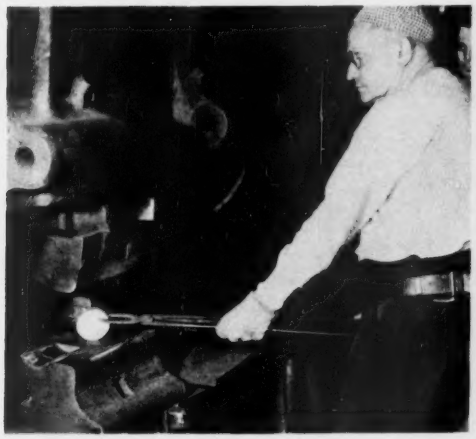
What's Happening at CRUCIBLE

about tool steel forgings

Whether 1½ pounds or 7 tons . . . forgings get the same sensitive handling

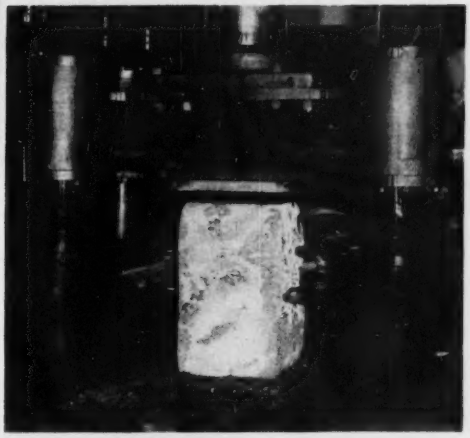
Crucible's reputation as the specialty steel leader is built on a devotion to the smallest detail . . . regardless of the size of the order.

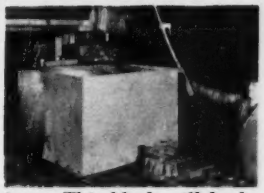
These forgings are good examples of Crucible specialists at work:



Rex M-2 High Speed Steel Disc Forging (1½ pounds)

Pancake forgings such as these are used extensively by small tool makers. Extreme care is taken in the preparation of the slug stock. The upsetting insures proper flow lines. Milling cutters, gear shavers and similar cutting tools that require maximum toughness, coupled with the best cutting ability, are made from these forgings.





CSM-2 Plastic Mold Forging (14,000 pounds)

This CSM-2 plastic mold steel forging was made from a 25,000-pound ingot. This block will be heat-treated and worked to produce a mold for the manufacture of large plastic parts. The finished weight of the forging is 14,000 pounds. And it is the largest mold forging yet produced by Crucible.

Engineering service available

Crucible's engineering service is geared to meet your research and development problems. If you use special forgings, or any special purpose steel, check with Crucible. Crucible Steel Company of America, General Sales and Operating Offices, Oliver Building, Pittsburgh, Pa.

CRUCIBLE first name in special purpose steels

52 years of Fine steelmaking

Midland Works, Midland, Pa. • Spaulding Works, Harrison, N. J. • Park Works, Pittsburgh, Pa. • Spring Works, Pittsburgh, Pa.
National Drawn Works, East Liverpool, Ohio • Sanderson-Halcomb Works, Syracuse, N. Y. • Trent Tube Company, East Troy, Wisconsin

5 a.m.

A bottle of milk is the last scene in the last act of the cow-to-cup drama.

The real stars in this drama are milking machines, pasteurizers, bottle washers, homogenizers, and delivery trucks. Synthane—a laminated plastic—plays an unseen but essential part in these and other kinds of electrical and mechanical dairy equipment.

The dairy industry appreciates, as you may, the fact that Synthane is strong light in weight, chemical-resistant, easily machined, and a good electrical insulator—all rolled into one. And that it is available in sheets, rods, tubes, and fabricated parts.

Try Synthane laminated plastics yourself. There is an interesting 26-page catalog of its properties and possibilities waiting for you. Synthane Corporation, 10 River Road, Oaks, Pennsylvania.

AIRCRAFT electronics system part, made from Grade LE Synthane. Application requires good electrical properties, resistance to moisture, retention of size and shape at elevated temperatures.

Synthane-one of industry's unseen essentials

SYNTHANE

LAMINATED PLASTICS

"Where opportunity knocks every day"

This huge new building pictured above is one of the world's most modern petroleum research laboratories—those of the Standard Oil Development Company at Linden, N. J. It is the research center where Esso Products are constantly developed and improved by engineers and technicians whose aim is better products for better living all over the world.

Here chemists and engineers find limitless opportunities for the scientific advancement of petroleum research. Scientific exploration in all the phases of oil production is constantly encouraged at Esso.

The 28,000 workers at Esso have been with the company an average of over 14 years . . . 8,600 of them for 20 years or more. Esso is proud to have this large number of long service employees, enjoying fair pay, good working conditions, and a chance to learn more about the oil business and to advance in the company.

It has been an Esso Management policy for more than 30 years to keep *good people* happy at *good jobs* . . . and turn out consistently *good products* that carry the Esso trade-mark.

Esso

ESSO STANDARD OIL COMPANY

briefing the news

(*Continued from page 40*)

see resemblances in a series of recurring figures. On this test, 12- to 14-year-old children do as well as adults.

The second factor is measured by a simple test which requires an individual to adjust a flashing light until it appears to be lit steadily.

Persons with good biological intelligence do not see the light flashes run together at a low rate. If biological intelligence is impaired, the flashes of light fuse together at a much lower rate than normal.

A third factor in biological intelligence involves various classes of memory, including the ability to recall the shape of objects by touch.

The fourth factor is called the modality factor, and is concerned with the mode by which biological intelligence is manifested. Some people write well and speak badly, others express their intelligence in painting, music or craftsmanship.

Halstead's researches indicate that from the age of 12 to the age of 35, actual age has little to do with biological intelligence for people who live in the western hemisphere. Biological intelligence between these ages is also independent of the amount of education an individual may have had.

Conventional IQ tests of mental age, do not take native or biological intelligence adequately into account, Halstead reported.

Cobalt Cancer "Bombs"

Radioactive cobalt cancer "bombs" have recently been installed in two Canadian hospitals.

Each bomb is worth about $50,000, and each does the work of a 2,000,000 volt X-ray machine that may cost as much as $200,000, or of a mass of radium worth $50,000,000.

The cobalt-60 in the Canadian bombs is the most powerful source of radioactivity ever used for a peaceful purpose in any country. It is about 200 times more powerful than the most powerful radium bombs now in use. Cobalt-60 is inexpensive, compared either with a powerful X-ray machine or a far larger amount of radium. With cobalt-60 it will soon be possible for even small hospitals to treat cancer as effectively as the large ones that have colossal X-ray machines.

Unlike radium, cobalt-60 is not a natural element. It is prepared by irradiating natural cobalt (cobalt-59) in an atomic reactor or "pile."

Cobalt-60 has half-life of 5.3 years, which means that in 5.3 years it will be only half as radioactive as it was originally and in another 5.3 years only a quarter. A bomb of cobalt-60 will be "dying" in three or four years, so that another must be substituted.

A bomb is a heavy leaden case a foot thick in which there is an ounce or so of cobalt-60. The lead absorbs most of the radiation and so protects the physicians and technicians in the bomb room. Through a small shuttered opening in the leaden case the gamma rays from the cobalt can be aimed at a tumor in a patient's body. Because the case is heavy, machinery is required to raise and lower it and move it sideways into the right position. Wherever a direct beam from a cobalt bomb may strike a wall, 40 inches of concrete must be provided. Walls and ceiling that may be exposed to scattered radiation will need 8 inches of concrete.

The cobalt-60 in the bomb is only half the size of a flashlight battery. Yet if you were to stand only three feet from that amount of unshielded cobalt-60 you would be fatally irradiated in a few minutes.

investment and the engineer

(*Continued from page 15*)

engineer in a distinctly favorable position.

Obviously, the major problem for a long term investor is to determine what to buy. We have seen that it is advantageous for the engineer to put some of his savings into companies in his field. However, it is useful to refer to different business sources for their opinions on the financial strength of the company which is being considered. This can be easily done by referring to the library. At M. I. T., for instance, the Dewey Library subscribes to many of the major advisory services, such as Moody's, Standard and Poor's.

Another major problem is that of timing. In other words, when is the best time to buy? It would appear that the best method would involve buying only during business recessions and major falls in the stock market. However, there are some difficulties. Major depressions are so far between and look so unlikely at the height of an inflationary period that it is the rare person who would wait patiently for them.

Many methods have been developed to overcome the above mentioned difficulties. Among the most popular today is "dollar-averaging." This is a very simple plan. It requires that at certain predetermined periods, say once a year, a specified amount of money is used to purchase a group of stocks which have previously been chosen. The same amount of money is used each year. There is one distinct advantage to the plan. This can best be illustrated by a specific example: Suppose you decided to buy each year one thousand dollars worth of a certain stock. The first year it sells for twenty dollars a share and so fifty shares are bought. The second year it sells for thirty dollars a share and thirty-three shares are bought. The average purchase price is, by this method, twenty-four dollars a share. We see that by this method the average purchase price will always be less than the average price over the same period, since fewer shares are bought at higher prices and more at lower prices. This is one plan of many of varying complexity. Its success depends to a great degree upon choice of stocks with strong growth trends.

The problem of investing in the large company as against the small one arises next. Suppose I am a physicist who is certain that companies dealing in construction of atomic plants have a bright future ahead of them. I can choose a number of corporations in which to invest, including Vitro Manufacturing and Monsanto Chemical. The first is a small company which is a major contractor for the AEC, while the second is one of the largest chemical companies, which operates atomic plants as a small sideline. Both are stocks which have strong growth potential, yet there are significant and sharp differences between them. Monsanto will afford a much higher degree of safety. However, under favorable conditions, it is possible for Vitro Manufacturing to expand many times more rapidly. Of course, the choice between these two extremes is up to the individual. When investing, determine the amount of risk you wish to take and choose accordingly.

This article should serve as an introduction to a field which can be of great importance to you in your future. If handled emotionally or hastily, the securities market can be as dangerous as horse racing, but if evaluated carefully with an eye to the long range future, the stock market can provide a basis for security and an income for retirement.

Television joins the microscope in a major scientific advance, pioneered at the David Sarnoff Research Center of RCA, Princeton, N. J.

Microbes star on Television in war against disease!

Until recently, scientists found it difficult to keep microbes alive for study—at high magnification—in light microscopes. Dyes, used to make them visible, killed some. Others were destroyed by the intense light.

RCA scientists have solved this problem by making television a working partner of the microscope. "Eye" of their new system is a tiny industrial television camera built around RCA's sensitive *vidicon* television tube. No intense light is needed, since this electron tube "sees" at extremely low light levels. And by making the tube sensitive to the red or violet bands of the spectrum, dyes and stains are eliminated.

With RCA's system, research men can watch living germs or cells—immensely magnified—on the screen of a television set. Many are able to watch at a time. Students can be more easily trained. And science *learns more* about disease by watching *live* micro-organisms.

Improving the microscope by teaming it with television is an example of the many paths explored by RCA Research. You benefit directly by better performance from any instrument or service of RCA or RCA Victor.

• • •

See the latest in radio, television, and electronics at RCA Exhibition Hall, 36 West 49th Street, N. Y. Admission is free. Radio Corporation of America, RCA Building, New York 20, N. Y.

CONTINUE YOUR EDUCATION WITH PAY—AT RCA

Graduate Electrical Engineers: RCA Victor—one of the world's foremost manufacturers of radio and electronic products—offers you opportunity to gain valuable, well-rounded training and experience at a good salary with opportunities for advancement. Here are only five of the many projects which offer unusual promise:

- Development and design of radio receivers (including broadcast, short-wave and FM circuits, television, and phonograph combinations).
- Advanced development and design of AM and FM broadcast transmitters, R-F induction heating, mobile communications equipment, relay systems.
- Design of component parts such as coils, loudspeakers, capacitors.
- Development and design of new recording and producing methods.
- Design of receiving, power, cathode ray, gas and photo tubes.

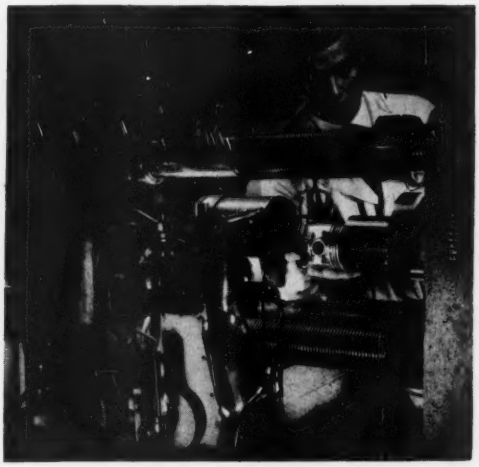
Write today to College Relations Division, RCA Victor, Camden, New Jersey. **Also many opportunities for Mechanical and Chemical Engineers and Physicists.**

RADIO CORPORATION OF AMERICA

World leader in radio—first in television

Opportunities with General Motors

Your Future as an Engineering School Graduate at GM



FOR many years General Motors has been recruiting graduates of the country's leading engineering schools.

A high percentage of these young men, through hard work and initiative, have made sound business careers for themselves at GM. In fact, today many GM divisional managers are engineering school graduates. So are many others in top management.

GM is not only a major producer of motorcars and trucks, but also a leading manufacturer of many types of civilian goods from heating systems to refrigerators, from fractional h.p. motors to Diesel locomotives.

And, as a top defense contractor, GM is building everything from rockets and shells to tanks and jet and Turbo-Prop engines.

In these many operations we require the services of all types of engineers to engage in all phases of engineering work—from pure research to production supervision.

This work is decentralized among GM's 34 manufacturing divisions, operating 112 plants in 54 towns and cities throughout the country. Each division operates as an independent unit with its own engineering department. Yet each benefits from the resources of GM's central research and engineering laboratories.

Thus, from the start, GM offers the engineering graduate both the opportunities and facilities of a large, successful organization and the friendly working environment of a smaller company.

For further information on a GM engineering career, we suggest you ask your College Placement Office to arrange an interview for you with the GM College Representative the next time he visits your campus.

GM POSITIONS ARE NOW OPEN IN THE FOLLOWING FIELDS:

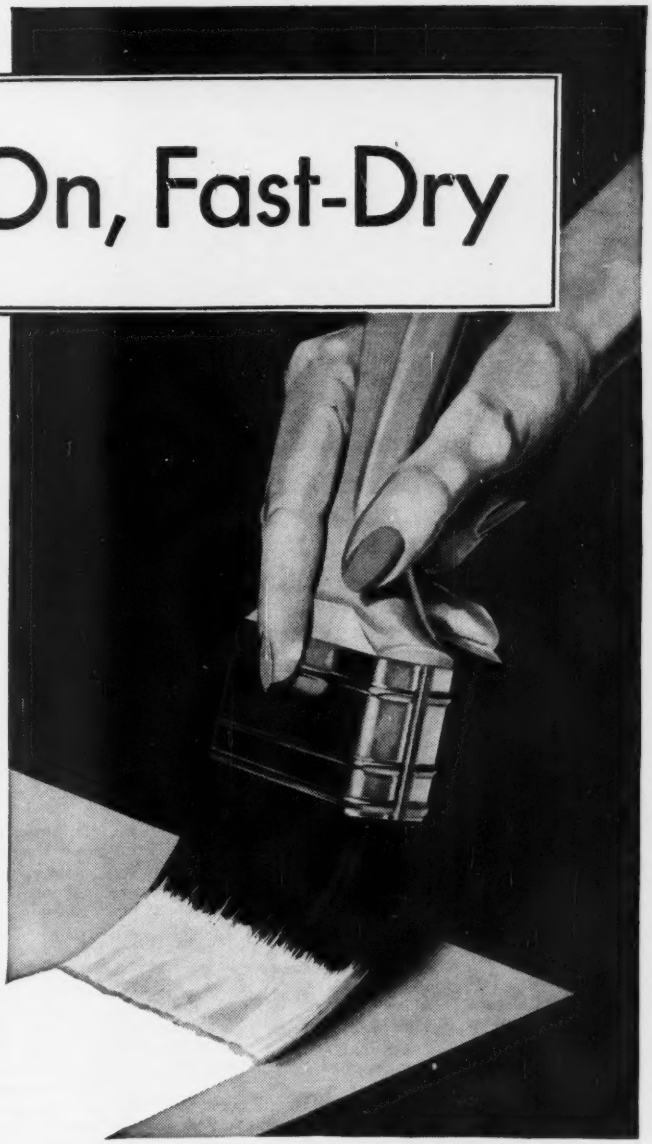
Electrical Engineering • Mechanical Engineering
Metallurgical Engineering • Chemical Engineering
Industrial Engineering

See December 1951 of Fortune Magazine for description of new multimillion dollar GM Research and Technical Center in Detroit.

GENERAL MOTORS CORPORATION

Personnel Staff, Detroit 2, Michigan

Easy-On, Fast-Dry



CHEMICAL PROBLEM...

. . . to help make enamels that combine fast drying and easy brushing—advantages not always found together in the two types of enamels most used today. One type of enamel brushes easier, the other dries faster.

SOLUTION . . .

. . . a new Hercules resin, Pentalyn® B-56. It reacts chemically with the other paint ingredients to favor neither drying speed nor brushing qualities unduly, but to provide the very best combination of both.

COLLEGE MEN...

This is but one example of the far-reaching chemical developments in which you could participate at Hercules—in research, production, sales, or staff operations. It suggests the ways Hercules' products serve an ever-broadening range of industries and end-uses.

Hercules' business is solving problems by chemistry for industry...

. . . paper, rubber, insecticides, adhesives, soaps, detergents, plastics, paint, varnish, lacquer, textiles, to name a few, use Hercules® synthetic resins, cellulose products, chemical cotton, terpene chemicals, rosin and rosin derivatives, chlorinated products, and other chemical processing materials. Hercules® explosives serve mining, quarrying, construction, seismograph projects everywhere.

HERCULES

HERCULES POWDER COMPANY Wilmington, Delaware
Sales Offices in Principal Cities

● ALBANENE,* a K&E product, is the preferred tracing paper in thousands of drafting rooms. It is transparentized, not with messy oils that leak, but with a special synthetic transparentizer developed by K&E. ALBANENE does not turn brittle or lose its transparency with time. After years it is as good as new. *Trade Mark®

KEUFFEL & ESSER CO.

EST. 1867

NEW YORK • HOBOKEN, N. J.

Chicago • St. Louis • Detroit • San Francisco • Los Angeles • Montreal

K+E

Drafting, Reproduction and Surveying Equipment and Materials. Slide Rules. Measuring Tapes.

waves at work

(*Continued from page 17*)

in receiving and relay stations, and as a local oscillator in relaying stations.

The invention of the magnetron, which with later development fulfills the requirements of power, high-frequency, and efficiency, is generally accredited to A. W. Hull, an American. At the time of its invention, 1921, he was employed by General Electric. Although Hull did not recognize the characteristics which make the magnetron applicable to modern microwave systems (traveling wave oscillations-electronic oscillations-cyclotron frequency oscillation, all being the same) he did take a big step in the right direction. From 1921 until 1937 the magnetron saw development in all parts of the world: Czechoslovakia, Japan, England, and the United States.

The magnetron was not given much attention by industry until 1940, when it was produced for widespread radar application in the United States. England, however, had set up a few radar stations in 1938.

The uses of the magnetron are: radar, medicine, nuclear science, dielectric heating, television, and meteorology. As is obvious, the development of the magnetron is closely related to those of microwaves themselves; it is a hand in hand operation.

The amplification problem is a very important one from the economic viewpoint. As was seen in relation to transmission, it was necessary to demodulate the microwave carrier into the subcarrier so that the signal could be amplified. If a suitable amplifier of microwaves could be made which would eliminate this demodulation and remodulation a great saving would be realized. Between 1945 and 1947 a step toward better amplification was made when the klystron (velocity variation tube) was replaced by a d.c.-operated triode radiation laboratory.

The most commonly used methods of modulation are: frequency modulation, pulse-code modulation. The former is established in the broadcasting bands because of its low susceptibility to noise. Basically what happens in FM is that the information of a relatively low frequency varies the frequency of a stable high frequency oscillator which acts as a carrier. In this manner a signal which has been frequency modulated once can again be frequency modulated at a higher frequency which in turn acts as the carrier for the carrier. In pulse-code modulation the output of the information signal is measured at uniform short intervals of time. Each time the information signal is measured a higher frequency signal is sent which describes the lower frequency waves amplitude. A stepwise time function is received. This is smoothed out into a continuous time function. This system is not susceptible to a reasonable amount of noise, because all that is necessary is that a number of "beeps" be received which are distinguishable from the noise. If the noise becomes too large it cancels the signal out altogether — making the system useless.

A typical long-distance microwave relay system is that of the American Telephone and Telegraph's TD-2, the New York to Chicago to San Francisco network. Its microwave band width is between 3700 and 4200 megacycles. This is broken down to six different two-way channels which are 40 megacycles wide and are centered on the frequencies 3750, 3830, 3910, 3990, 4070, and 4150 megacycles.

In building the first section of this network, concrete towers were used because of lack of steel; however, when steel became available, steel towers were used. By having a long system in which each relay station must be in the "line of sight" of the next one, the stations had to be, on the average, placed from twenty-five to thirty miles apart. This obviously calls for a considerable number of these intermediate stations. Because it would be too expensive to have a repairman at each station all the time, elaborate safety devices were used. These automatic devices turn on auxiliary generators, and notify a main repair station of the whereabouts of the trouble and shut off redundent equipment.

The art of utilizing microwaves from the time Hertz, in 1887, found that the reflection of radio waves from metal bodies could be detected has progressed a long way — seeing their greatest development in radio communications as stimulated by world war II. But they have also been put to use and studied in the no less important fields of nuclear physics, and medicine. What the future holds for their use would be a continually changing prediction because of the continued rapid development for military and civilian purposes.

Security

A FAMILY had failed to make a living on a worn-out New England farm. Did they demand government subsidies, checks for crops they didn't raise, high prices for crops to be burned?

They would have scorned such things—scorned and feared, for they knew from days under a foreign despot that where government *money* goes, government *control* goes, too.

No, this family put everything they owned in that wagon, and *walked* beside it 2,000 miles, westward. They didn't know what was ahead, but they were determined to keep on going until they found a place of freedom where they could keep their self-respect.

They were English, Scotch, Dutch, Italian, French—people from many places—all, now, Americans. They knew that the only happiness is from self-respect, and the only way to self-respect is to earn your own way, not whine for something for nothing.

Their sons and grandsons started grocery stores, became mechanics, saved their money and started factories. American machines bought by American thrift made the factories grow.

And that's America. Made by people willing to walk 2,000 miles beside a wagon—to find opportunity. If such people are gone, if all we've got left are soft weaklings who want to be taken care of, then in truth American manliness is dead, that 2,000 mile walk was wasted, and there is nothing left of America but a hollow shell.

WARNER & SWASEY
Cleveland
Machine Tools
Textile
Machinery

YOU CAN MACHINE IT BETTER, FASTER, FOR LESS WITH WARNER & SWASEY TURRET LATHES, AUTOMATICS AND TAPPING MACHINES

Hitting modern military targets poses ever-new engineering problems

Increasing emphasis in speed and mobility in modern warfare intensifies the problem of destroying the target—takes it out of the reach of manual ability and into the realm of electronics. Electrical and mechanical engineering—of the highest skill and ingenuity—are required.

Since 1918, Arma Corporation has worked closely with our Armed Forces and American Industry in pioneering and developing equipment to solve such problems. Today, Arma is in the forefront in supplying these precision instruments for our nation's defense, through techniques which tomorrow can be widely applied.

This booklet—"Engineering at Arma"—describes in detail the challenges of an engineering career at Arma. It can open new horizons to you. Write today for your copy to Engineering Division, Arma Corporation, 254 36th Street, Brooklyn 32, N. Y.

ARMA CORPORATION
254 36th Street, Brooklyn 32, N. Y.
SUBSIDIARY OF AMERICAN BOSCH CORPORATION

QUALITY ARMA PRECISION
INSTRUMENT

34 YEARS OF LEADERSHIP IN INSTRUMENTATION

The Torrington Needle Bearing is designed for high radial loads

The many lineal inches of contact provided by the larger number of small diameter rollers give the Torrington Needle Bearing an unusually high load rating. In fact, a Needle Bearing has greater radial capacity in relation to its outside diameter than any other type of anti-friction bearing. This is illustrated in the table below, which compares the dimensions of three bearings with identically rated radial load capacities.

	O. D.	I. D.	Axial Length
Torrington Needle Bearing No. B-1616	1¼"	1"	1"
Ball Bearing No. 405	3.15"	.98"	.83"
Bronze Bushing 3 sq. in area of bearing surface	1⅞"	1½"	2"

Dimensions for three types of bearings, all having the same rated radial load capacity.

Precision Manufacture and Unique Design

The exceptional load capacity of the Needle Bearing is the result of proper selection of steels, precision workmanship to close tolerances, and the application of modern anti-friction principles.

The one-piece shell, which serves as the outer raceway and retains the rollers, is accurately drawn from carefully selected strip steel. After forming, it is carburized and hardened. There is no further grinding or other operation that might destroy the wear-resistant raceway surfaces. The full complement of thru-hardened, precision-ground rollers is retained by the turned-in lips of the one-piece shell.

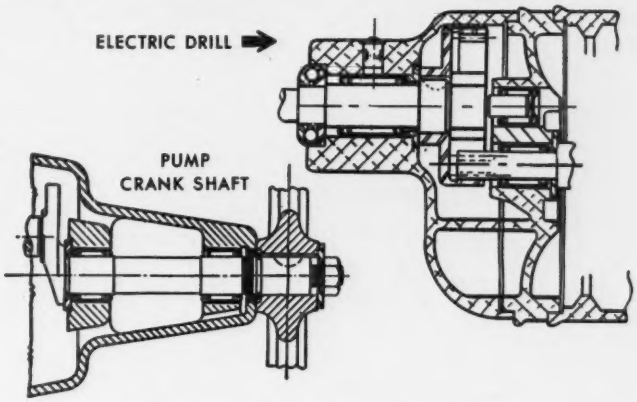
As the shaft is intended to serve as the inner race in most applications, it is hardened and ground to correct size. If an unhardened shaft is desirable, inner races can be furnished with the proper hardness.

Plus Features For Modern Design

The unit design and compact size of the Torrington Needle Bearing provide other, related advantages which are being utilized in more and more applications.

The outer shell is easily seated by press fit into a straight bore housing, machined to the proper dimensions. No complex housing structures are needed – no spacers, retainers or snap rings required. And the compact size and light weight of the bearing itself also help make the end product lighter and less bulky.

Wherever high radial load capacity is vital, but space and weight are at a premium, Torrington Needle Bearings provide an ideal solution.



High radial load capacity is vital in many bearing applications.

Future advertisements in this series will discuss other specific advantages of Needle Bearings. If you would like further information on these or any other type of anti-friction bearings, our engineering department will be glad to be of assistance.

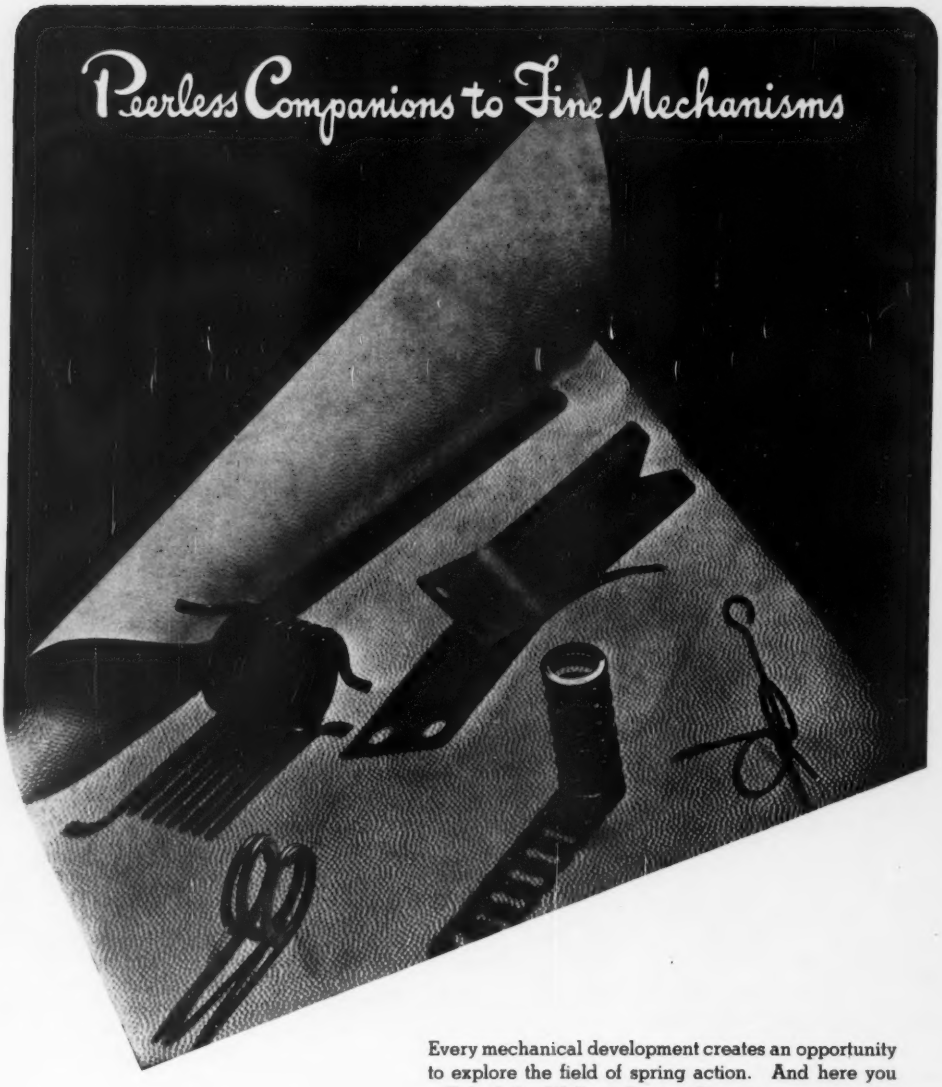
THE TORRINGTON COMPANY

Torrington, Conn. • South Bend 21, Ind.

District Offices and Distributors in Principal Cities of United States and Canada

TORRINGTON NEEDLE BEARINGS

NEEDLE • SPHERICAL ROLLER • TAPERED ROLLER • STRAIGHT ROLLER • BALL • NEEDLE ROLLERS



Every mechanical development creates an opportunity to explore the field of spring action. And here you will find the Wallace Barnes Company your partner in mechanical progress. For Wallace Barnes shares its specialized research and knowledge through technical assistance to design engineers in industry.

Wallace Barnes Springs

Bristol Connecticut

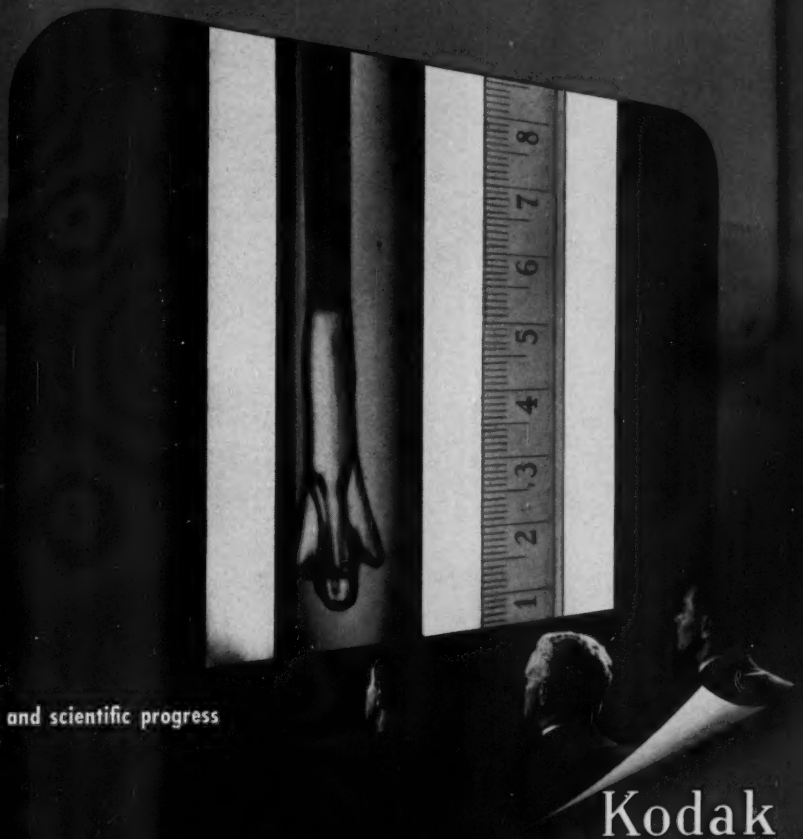
Springmakers for four generations

Engineering has a precision tool in photography

WHATEVER YOUR BRANCH of engineering, you'll find photography an increasingly valuable aid. With it you can picture lightning-fast operations—or extremely slow processes—at speeds suitable for study. You can capture fleeting instrument traces, study internal stresses in machine parts, examine metal structure and do countless other things.

The application of photography to engineering problems has become a specialty in itself. This has led graduates in the physical sciences and in engineering to find positions with the Eastman Kodak Company. If you are interested, write to Business and Technical Personnel Department, Eastman Kodak Company, Rochester 4, N. Y.

Here high speed motion-picture photography shows a cavity in a column of water produced when a 5-mm rod was shot through it at 12.2 meters per second. By taking the pictures at 8200 per second and projecting them at the standard 16 per second, time is "magnified" 200 times.

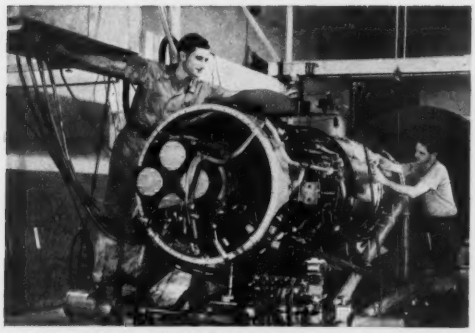


FUNCTIONAL PHOTOGRAPHY

serves industrial, commercial, and scientific progress

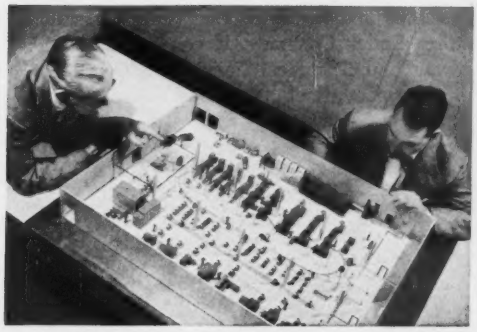
Kodak

Five Ways to Begin Careers with General Electric

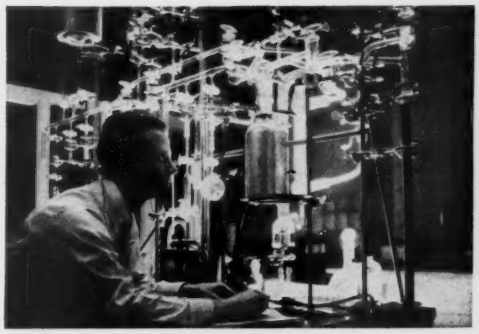


1. TEST ENGINEERS PROGRAM—gives engineering graduates opportunities for careers not only in engineering but in all phases of the company's business. Rotating assignments plus opportunities for further classroom study.

2. BUSINESS TRAINING COURSE—open to business administration, liberal arts and other graduates...for careers in accounting, finance, administration.



3. MANUFACTURING TRAINING PROGRAM—for developing manufacturing leaders. Open to graduates with a technical education or a general education with technical emphasis.



4. CHEMICAL AND METALLURGICAL PROGRAM—offers rotating assignments and studies for chemists and for chemical and metallurgical engineers.

5. PHYSICS PROGRAM—the gateway by which physics majors begin G-E careers. Program graduates have gone into such fields as research, development, manufacturing, design, marketing.

If you are interested in entering one of these five basic General Electric programs after graduation, talk with your placement officer and the G-E representative when he visits your campus. Meanwhile, send for further information:

- **On Test, Chemical and Metallurgical, and Physics Programs, write to Technical Personnel Services Dept., Schenectady, N. Y.**
- **On Business Training, write to Business Training Course, Schenectady, N. Y.**
- **On Manufacturing, write to Manufacturing Personnel Development Services Department, Schenectady, N. Y.**

GENERAL ELECTRIC